DESCRIPTION OF
INTEGRATED TERMINAL WEATHER
SYSTEM (ITWS)
WEATHER PRODUCTS

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ITWS Program Office
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This work was developed by MIT Lincoln Laboratory for the Federal Aviation Administration Integrated Terminal Weather Sysytem (ITWS) Program. It is a draft of the documentation to be used for ITWS training to be performed by the Raytheon, the ITWS contractor. Comments concerning this document are greatly appreciated and should be forwarded to the ITWS Program Office.

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LIST OF ACRONYMS

2-D	Two-dimensional
3-D	Three-dimensional
ACARS	Aircraft Communications Addressing and Reporting System
AP	Anomalous Propagation
ARP	Airport Reference Point
ARTCC	Air Route Traffic Control Center
ASOS	Automated Surface Observing System
ASR	Airport Surveillance Radar
ATA	Arrival Transition Areas
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
AWOS	Automated Weather Observing System
CWSU	Center Weather Service Unit
DAL	Dallas Love Airport
DFW	Dallas-Ft. Worth International Airport
DTA	Departure Transition Area
FAA	Federal Aviation Administration
FSD	Full Scale Development
ITWS	Integrated Terminal Weather System
LLWAS	Low Level Windshear Alert System
MBA	Microburst Alert
MDCRS	Meteorological Data Collection and Reporting System
NLDN	National Lightning Detection Network
NWS	National Weather Service
PIREP	Pilot report
POSH	Probability of Severe Hail
RUC	Rapid Update Cycle
SD	Situation Display
TDWR	Terminal Doppler Weather Radar
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
VCP	Volume Coverage Pattern
WSA	Wind Shear Alert

I. INTRODUCTION

The Integrated Terminal Weather System (ITWS) is a development program initiated by the Federal Aviation Administration (FAA) to produce a fully-automated, integrated terminal weather information system to improve the safety, efficiency and capacity of terminal area aviation operations. The ITWS will acquire data from FAA and National Weather Service (NWS) sensors as well as from aircraft in flight in the terminal area, as indicated in Figure I.1. The ITWS will provide products that are immediately usable without further meteorological interpretation to Air Traffic personnel, air traffic management systems (*e.g.*, Center-Terminal Radar Approach Control [TRACON] Automation System), pilots, and airlines. These products include current terminal area weather and short-term (0-20 minute) predictions of significant weather phenomena.

The ITWS provides products that will enable air traffic and airline users to significantly improve safety and reduce delays at major terminals and in the enroute airspace that surrounds these terminals. Table I.1 summarizes the safety enhancements by the ITWS while Table I.2 summarizes the delay reduction/efficiency enhancements identified in operational testing with functional ITWS prototypes at Memphis, Orlando, and Dallas/Ft. Worth International Airports from 1994 through 1997 and discusses how safety is enhanced by ITWS over the Terminal Doppler Weather Radar (TDWR) and Airport Surveillance Radar (ASR)-9 systems.

The ITWS is currently in full-scale development (FSD) by the FAA. The production ITWS systems are being developed by the Raytheon Company. Delivery of four pre-production systems is scheduled for 1999 with full-scale deployment to commence in 2001.

The ITWS functional prototypes are continuing to operate while the FSD is underway to reduce risks and investigate enhancements of the basic ITWS capability. One of the important elements of risk reduction is the use of a color Situation Display (SD) that has the key functional features of the specified FSD SD. This document has been prepared as a product guide for users of the prototype SD.

This document contains a separate section for each weather information product. Within each section the discussion is broken down into subsections including a general description of the product, what data sources are used by the product, how the product is generated from the input data, what caveats in the technical performance apply, how the product is displayed, and how the product might be used to enhance safety and support decision-making for traffic management. Some examples of the products are included to show what they look like on the prototype SD screen. (The SD described in this document is similar to, but not exactly the same as, the SD that will be delivered with the production ITWS system.)

The document "Situation Display Users' Manual for the Integrated Terminal Weather System (ITWS)" (FAA, 1998) provides a description of the ITWS SD. It addresses the appearance of the ITWS products on the SD and the ways in which the end-user can interact with the products and control product presentation.

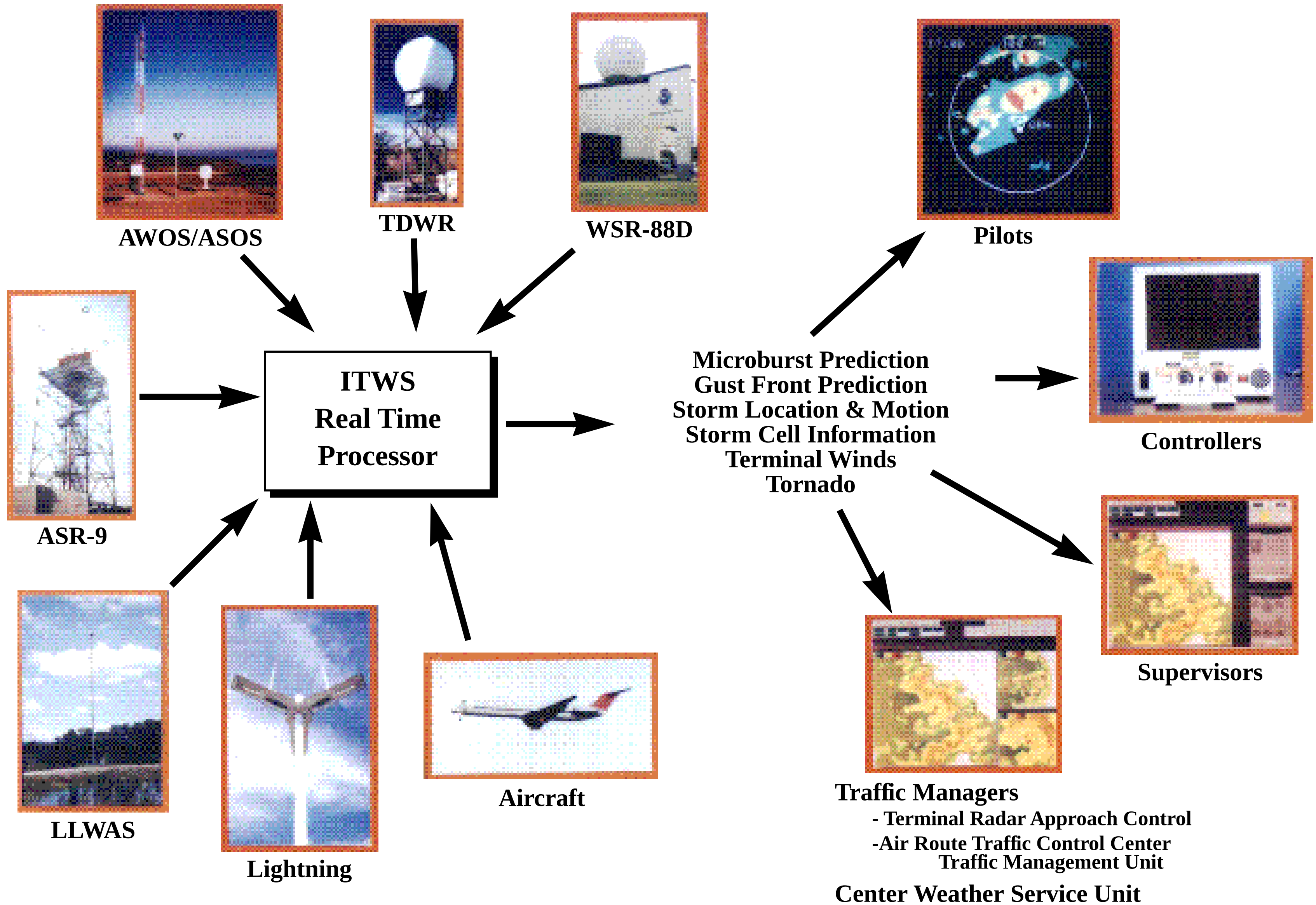

Figure I.1. ITWS input sensors, processing, and users.

Table I.1 Safety enhancements with ITWS products.

SAFETY CONCERN	ITWS PRODUCT(S)	HOW SAFETY IS ENHANCED BY ITWS (Above and Beyond TDWR and ASR-9)
Rapidly intensifying microburst	Microburst Prediction	Provides two- to five-minute predictive warnings
Extreme microbursts with airspeed losses greater than 60 knots requiring total avoidance (*e.g.*, Andrews Air Force Base event that narrowly missed President Reagan in Air Force One)	Microburst Prediction	Provides predictive strength estimate
Controller overload and pilot deviations from normal paths yielding “operational errors”	Precipitation, Storm Cell Information, and Storm Motion/Extrapolated Position	Shows location and movement of significant weather so Air Traffic can <u>proactively</u> plan a safe, efficient flow of aircraft
Tornadoes (*e.g.*, a tornado narrowly missed Orlando in 1998)	Tornado	Provides point location of tornadoes (TDWR provides no information on tornadoes)
Hail storm (*e.g.*, such as hit Dallas-Ft. Worth in 1995)	Storm Cell Information	Shows location and movement of hail storms (TDWR provides no information on hail.)
Mesocyclone (frequently causes tornadoes and/or damaging winds)	Storm Cell Information	Shows location and movement of mesocyclones (TDWR provides no information on mesocyclones.)
High reflectivity storm location and movement (identified as a high priority by National Transportation Safety Board) (*e.g.*, American Airlines DC10 accident at Dallas-Ft.Worth International Airport in 1993)	Precipitation, Storm Cell Information, and Storm Motion/Extrapolated Position	TDWR does not provide adequate vertical coverage over two thirds of the TRACON and is subject to attenuation. ASR-9 at times has false storm depictions due to anomalous propagation and is not always viewed as reliable by controllers.
Lightning	Storm Cell Information, Lightning	Shows location and movement of storms with lightning (TDWR and ASR-9 have no lightning information). Indicates when lightning is detected within 20 nm of the airport.

Table I.2 . Delay reduction/efficiency enhancement benefits due to better ATC decision-making with ITWS products.

ATC Decision	Magnitude of Benefit
Improving traffic merging and sequencing during adverse wind conditions at airports that have inadequate capacity during Instrument Meteorological Conditions	Extremely high
Recognizing that a runway will remain open as thunderstorms pass	Very high
Anticipating departure transition area (DTA) closure	High
Anticipating arrival transition area (ATA) closure	High
Anticipating re-opening of an ATA	High
Landing, rather than holding, aircraft before airport shutdown	High
Minimizing diversions before airport shutdown	High
Minimizing diversions near airport re-opening	High
Anticipating airport re-opening	Moderate
Positioning holding aircraft for quicker landings	Moderate
Landing more airplanes before arrival rate reductions	Moderate
Balancing DTA traffic better	Moderate
Reducing the duration or ground stops	Moderate
Anticipating runway shifts due to thunderstorms	Low
Reducing terminal flying distances	Low
Holding jets higher	Low
Recognizing advantageous ground stops better	Low
Improving use of severe weather avoidance programs	To be determined

An example of the ITWS Prototype SD is provided in Figure I.2. The upper portion of the display contains the Display Configuration Buttons, the Product Status Buttons, and the Alerts Section. The lower portion of the display contains graphics windows and text products windows. (No text products are displayed in Figure I.2.) The principal focuses of this document are the products and how they are depicted in the lower portion of the display and in the Alerts Section.

There may be more than one airport associated with the system that generates the ITWS products (herein referred to the ITWS product generator). The example of multiple airports used in this document is the Dallas/Ft. Worth Terminal Radar Approach Control (TRACON) that contains two

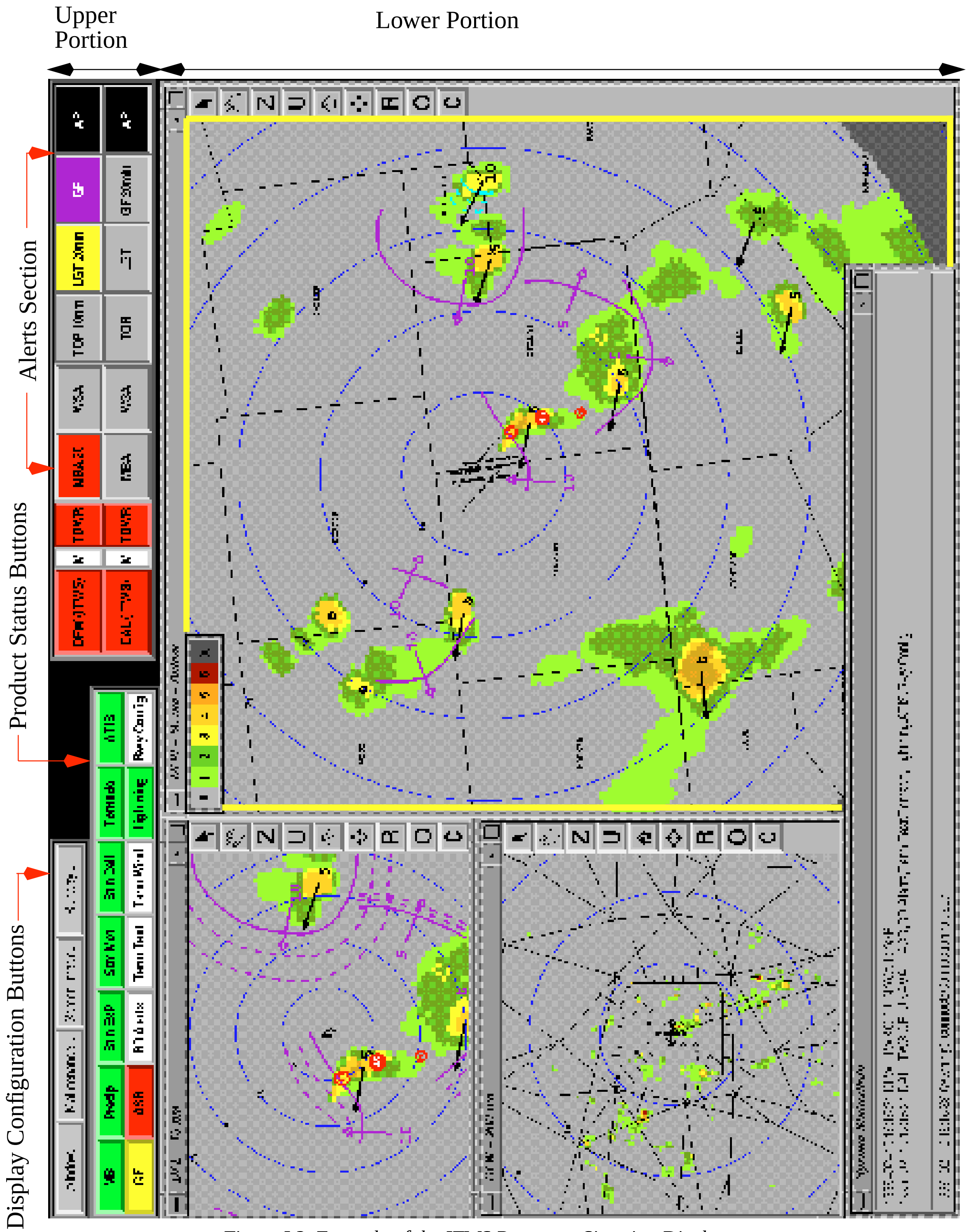

Figure I.2. Example of the ITWS Prototype Situation Display.

airports; Dallas/Ft. Worth International (DFW) and Dallas/Love Airports (DAL). The Alerts Section contains a line of alert boxes for each airport associated with the ITWS product generator.

The prototype SD at the Prototype ITWS Field Site locations do not provide all of the functional capability of a production ITWS SD. They support most (but not all) of the ITWS products and do not provide the fallback capability intended for the production system. Therefore, TDWR and Low Level Windshear Alert System (LLWAS) product display features will not be discussed here.

The following chapters are devoted to describing the ITWS products, their display concepts, and their performance.

II. 5-NM PRECIPITATION PRODUCT

II.1 TDWR Product

The 5-nm Precipitation product is a representation of the location and intensity of precipitation reaching the ground, as indicated by the TDWR surface scan. When the TDWR is in Monitor Scan Mode, the 5-nm Precipitation product covers the full 360 degrees around the TDWR radar. When the TDWR is in Hazardous Scan Mode, the product covers the “hazardous sector” (typically a 120-degree azimuth sector centered on the airport) only.

II.2 Display Concept

The 5-nm Precipitation product is provided in the standard NWS six-level representation. The levels are color-coded; greens represent lighter precipitation, reds represent heavier precipitation. The user may choose which of the weather levels (one through six) are displayed in the SD graphics products windows. In addition, precipitation intensities below level one are represented by light gray, TDWR attenuation is medium gray, and no data regions (areas where the TDWR scan does not provide coverage) are represented by dark gray.

The resolution of the 5-nm Precipitation product is 0.13 nm. The maximum range of the 5-nm Precipitation product is five nautical miles, centered on the Airport Reference Point (ARP). The update rate is every one to five minutes, depending upon the scan strategy.

II.3 Caveats

The 5-nm Precipitation product is updated every one to five minutes (depending on the scan strategy) while the ASR-9-based products (Chapter III) are updated every 30 seconds and the Weather Service Radar (WSR)-88D-based precipitation products (Chapter IV) are updated every five to six minutes (when thunderstorms are present). The weather levels associated with the 5-nm Precipitation product will probably differ from the weather levels in the other products where the products overlap because of the differences in update rate, product resolution, and sensor characteristics. For example, the 5-nm Precipitation product shows the intensity of precipitation at the altitude of the radar beam while the ASR-9-based products show the intensity of the precipitation over the depth of the storm and the WSR-88D provides the maximum intensity in a vertical column above a point.

If the 5-nm Precipitation product is unavailable, the TRACON precipitation product (Chapter III) is displayed as a fallback product.

II.4 Operational Use

This product is used for traffic management and situational awareness. The intensity of the precipitation can be used to identify areas of weather pilots are likely to avoid, aiding in optimization of traffic patterns. In combination with storm motion and storm extrapolated position, this product can be used to determine when weather will impact runways and when these impacts will end. This information can be used to maintain a higher effective capacity during thunderstorm conditions.

III. TRACON AND AP-FLAGGED PRECIPITATION PRODUCTS

The TRACON Precipitation product is a representation of the location and intensity of weather in the TRACON area. The basis for this product is the ASR-9 radar's weather channel output. At airports with more than one ASR-9 radar, the TRACON Precipitation product is a mosaic of all of the ASR-9 data. The TRACON Precipitation product is displayed by default in the SD graphics windows. An example of the product (a mosaic) is provided in Figure III.1.

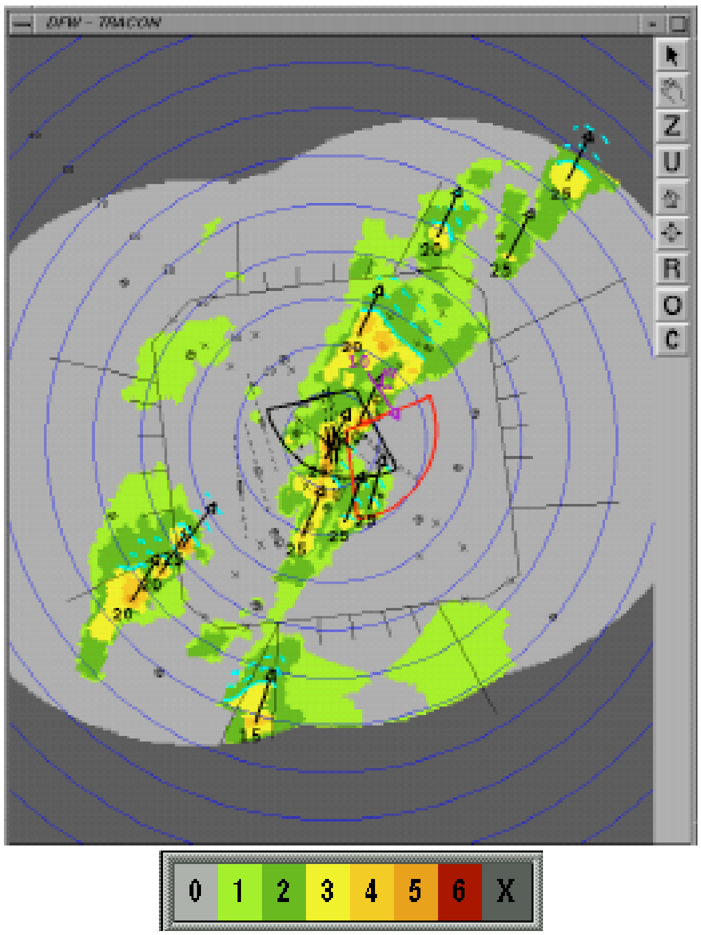

Figure III.1. Example of the TRACON Precipitation product.

The AP-Flagged Precipitation product explicitly shows where AP (anomalous propagation) clutter is located relative to any ASR-9 radar in a specified list of ASR-9 radars. An example of this product is provided in Figure III.2.

If operationally significant AP clutter is detected for any of the individual ASR-9 radars in the specified list, the AP alert panel in the Alerts Section will turn black with white "AP" text as shown

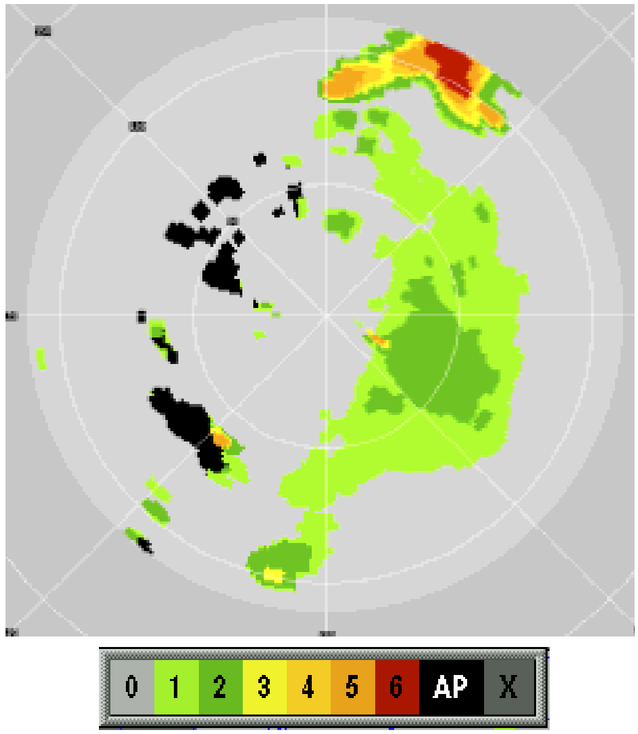

Figure III.2. Example of the AP-Flagged Precipitation product.

in Figure III.3. If the user chooses to look at the AP-Flagged product, the AP clutter will be shown as areas of black (Figure III.2).

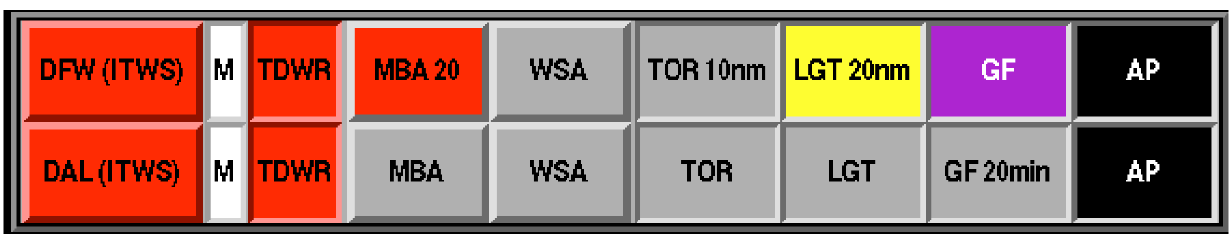

Figure III.3. Alerts Section showing the AP Alert panel (at the far right) when operationally significant AP has been detected.

III.1 ASR-9 Weather Channel

The width of the ASR-9 beam is 1.4 degrees in azimuth and greater than five degrees in elevation. This is known as a “fan beam” radar. The radar completes a full 360-degree scan in about five seconds. The primary purpose of this radar is to detect aircraft from the surface to 20,000 feet.

In addition to aircraft detection capabilities, the ASR-9 provides information on the location and intensity of precipitation in the TRACON area. The energy emitted by the radar reflects off raindrops in the atmosphere. The amount of energy reflected indicates the size and number of the raindrops present; heavy rain is associated with higher intensity levels. The returned signal is passed through a filter that removes ground clutter. The data are smoothed in time over six antenna rotations which results in a 30-second update rate of the precipitation data. The data are also smoothed in space to a resolution of 0.5 nm. During this smoothing process, the spatial extent of the highest intensity levels becomes exaggerated. The output is provided in the standard NWS six-level intensity scale.

III.2 Anomalous Propagation (AP)

The data from the ASR-9 weather channel are often contaminated by ground clutter due to AP. In the standard atmosphere, a radar beam typically travels in a slightly curved path (Figure III.4).

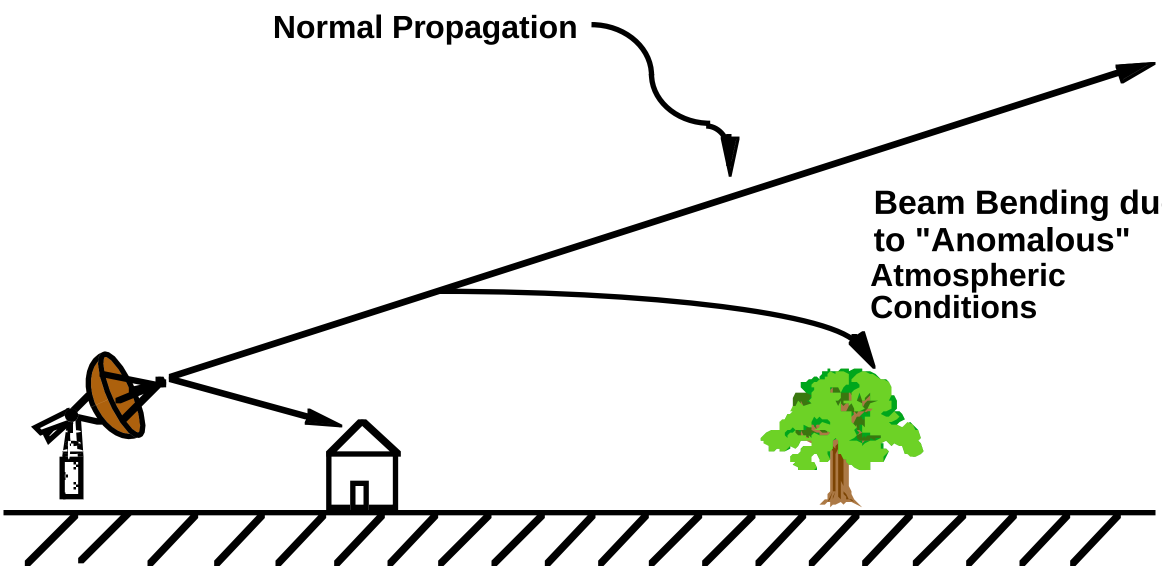

Figure III.4. Illustration of a radar beam propagating anomalously due to non-standard atmospheric conditions.

Under "anomalous" atmospheric conditions, the path of the beam is more highly curved and may strike the ground. The returns from the ground are often referred to as "anomalous propagation clutter." Because of the spatial and temporal smoothing performed by the weather channel processing, it is difficult for a user to look at an ASR-9 display and distinguish AP clutter from real weather signals.

The atmospheric conditions that cause AP are temperature inversions and moisture gradients. In a standard atmosphere, temperature decreases with height. Sometimes on a clear night, surface cooling reverses the temperature profile such that temperature increases with height near the ground. In this situation, the ASR-9 radar beam is bent downward and strikes the earth's surface. The ground returns look like real weather on the ASR-9 display. Although the skies may be cloud-free, this "nocturnal inversion" causes what seems to be weather returns to appear on the ASR-9 displays. As the inversion strengthens throughout the night, the AP clutter increases in spatial extent and intensity. This condition often causes the AP clutter that users see in the late night to early morning hours (Figure III.5a). At the time of this image, the skies were cloud-free.

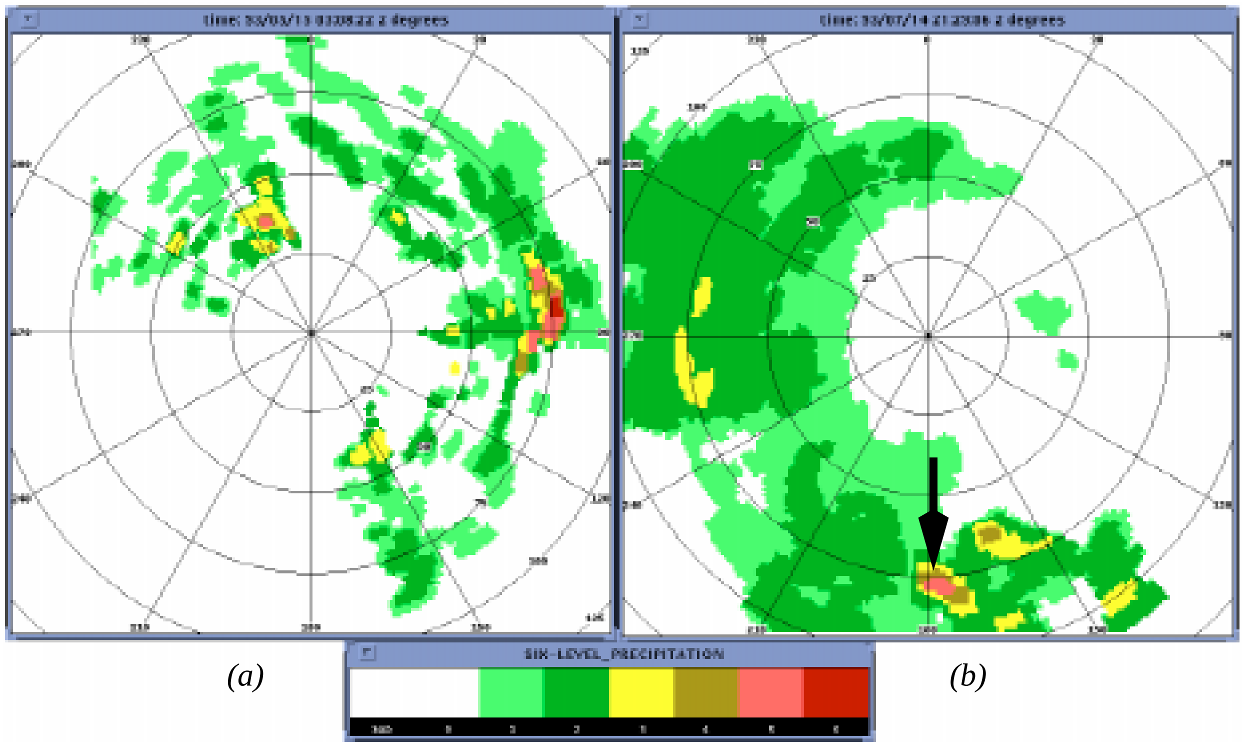

Figure III.5. Examples of AP clutter in ASR-9 weather channel data.

In addition to the nocturnal inversion situation, the passage of a cold thunderstorm outflow over or near the ASR-9 site sets up an inversion condition (cold air near the ground, warm air aloft) causing AP. In this case, valid weather returns co-exist with, and may even be contaminated by, AP clutter returns. In the latter case, the intensity of real weather appears to be greater than it actually is (Figure III.5b). The level five weather indicated by the arrow is in reality level three.

III.3 Removing AP Clutter from ASR-9 Data

AP clutter is removed from the ASR-9 data by comparing the ASR-9 returns to the WSR-88D Composite Maximum Reflectivity product and, where possible, a TDWR composite reflectivity product. Due to the “fan beam” nature of the ASR-9 radar, the weather shown on the display represents a vertical average of the weather over the depth of the beam. Although the ASR-9 radar locates the weather very well, information about the vertical distribution of reflectivity in storms is lost. This vertical information is regained from the WSR-88D and TDWR radars, which are called pencil-beam radars and have a 1-degree and 0.5-degree beamwidth, respectively. The pencil-beam radars perform successive scans at increasing elevation angles. This set of scans is commonly referred to as a Volume Coverage Pattern (VCP). The composite reflectivity products are created by converting the radial data from each of the elevation scans to a grid and identifying the maximum reflectivity in the column above each grid point. It takes five to 10 minutes to collect all of the WSR-88D data and 2.5 to five minutes to collect all of the TDWR data that go into the composite products. The data collection time depends upon the radar scan strategy in use.

To remove AP clutter from the ASR-9 data, the ASR-9 scan that occurs closest to the middle of the VCP is compared to the corresponding area in pencil-beam radar products. Each ASR-9 grid point that contains a valid value is tested against the corresponding value in the pencil-beam data to determine if the ASR-9 value is contaminated by AP clutter. Based on a set of rules, an AP clutter map is built from this comparison. This AP clutter map is used to edit the next-available ASR-9 map received after the pencil-beam data. As further ASR-9 updates become available (at 30-second intervals), only those grid points that are deemed to have contained AP clutter from the original comparison plus those nearby (*e.g.*, within 1.5 nm) are removed. A new map is created with each pencil-beam update.

For airports with multiple ASR-9 radars, AP clutter is removed from the data of each ASR-9 separately. A mosaic of all of the edited ASR-9 data is then created. The mosaic is displayed on the SD as the default TRACON Precipitation product.

III.4 Display Concept

The TRACON Precipitation products are provided in the standard NWS 6-level representation. The levels are color-coded as shown in Figure III.1; greens represent lighter precipitation, reds represent heavier precipitation. The user may choose which of the weather levels (one through six) are displayed in the SD graphics products windows. In addition, precipitation intensities below level one are represented by light gray and no data regions (areas where there is no coverage by the ASR-9 radar(s)) are represented by dark gray.

The colors used for the AP-Flagged Precipitation product (Figure III.2) are the same as the TRACON Precipitation product except that AP clutter is indicated in black. Users can not control the display of the weather levels for the AP-Flagged Precipitation product.

The resolution of the TRACON and AP-Flagged products is about 0.5 nm. The maximum range of the TRACON product is dependent upon the coverage of the individual ASR-9 radar that compose the mosaic. The maximum range of the AP-Flagged product is the same as the coverage of the individual ASR-9 radars; about 50 nm. The update rate for all ASR-9-based products is 30 seconds.

III.5 Caveats

Underestimation in radar "cone of silence". The accuracy of the weather depiction from a single ASR-9 radar is a function of range from the radar. In addition, the weather level reported by the ASR-9 weather channel is a vertically averaged estimate of storm intensity. For any radar that does not point vertically, there is a area above the radar that is not scanned. This area is known as the "cone-of-silence." Weather occupying the cone-of-silence is incompletely sensed by the radar. In Figure III.6, the beam does not intercept the high reflectivity core aloft, resulting in an underestimation of the intensity of the weather near the radar.

Underestimation due to aggressive ground clutter editing. The ASR-9 radars may also underestimate precipitation reaching the ground at sites with high-level ground clutter returns near the radar. Typically the radar systems at these sites are tuned to aggressively remove ground clutter

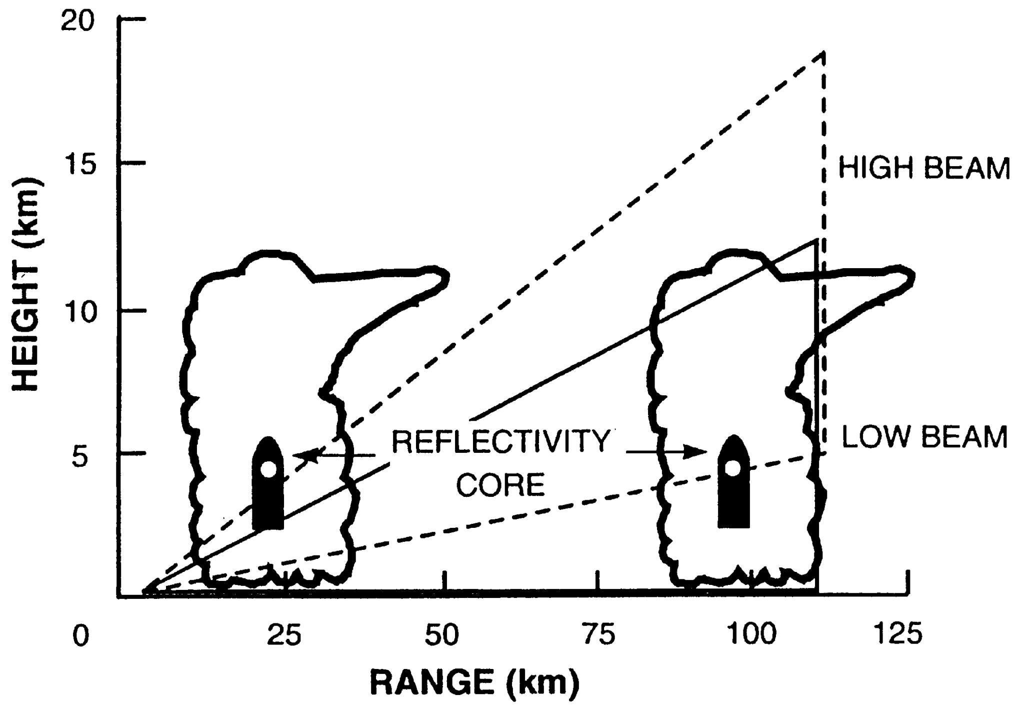

Figure III.6. An illustration of how the ASR-9 might produce an underestimate of storm intensity.

near the radar. Consequently, precipitation returns may be removed by the ground clutter editing. This may not be an operational problem for the ITWS sites where the TRACON precipitation product is a mosaic because data from the other ASR-9 radars may be used to provide product coverage above each individual ASR-9 radar. However, at the sites where the TRACON precipitation is derived from a single ASR-9 radar, it is recommended that users use the TDWR precipitation product (Chapter II) to provide information on precipitation near the airport.

Underestimation at long ranges. At long ranges, the vertical extent of the beam intercepts more than 30,000 feet of altitude while the storm core may occupy about 9000 feet (Figure III.6). Thus, the vertical average over the depth of the beam is likely to produce an underestimate of storm intensity.

AP clutter breakthrough near WSR-88D radars. The pencil-beam radars also have a cone-of-silence within which the weather is not completely sensed. Since it is impossible to know the true value of the weather in these cones-of-silence, ASR-9 returns within a threshold distance (*i.e.*, 7.5 nm for the WSR-88D) of the pencil-beam radars are not edited unless there is supporting evidence from other pencil-beam radars.

AP clutter breakthrough due to conservative editing. The philosophy of the AP-editing technique is to remove as much AP clutter as possible without removing valid weather signals. Thus, the AP-editing approach is conservative. AP clutter may remain in the map so that valid weather returns will not be erroneously removed. This is most likely to occur when there is weather in close proximity to the AP clutter. In addition, if there is no pencil beam radar data to support AP-editing, the ASR-9 data are passed to the mosaic process unedited. In such cases AP clutter may contaminate the mosaic and AP-flagged products.

AP clutter breakthrough due to growth. AP clutter is identified by comparing the ASR-9 scan closest to the middle of the pencil-beam VCP. AP clutter often grows like weather, increasing in spatial extent and intensity. Only those grid points that have been determined to contain AP clutter in the initial ASR/pencil-beam comparison are edited. If AP clutter develops in other grid points, it will remain in the TRACON precipitation product until the next comparison is made. An example of AP clutter breakthrough is shown in Figure III.7.

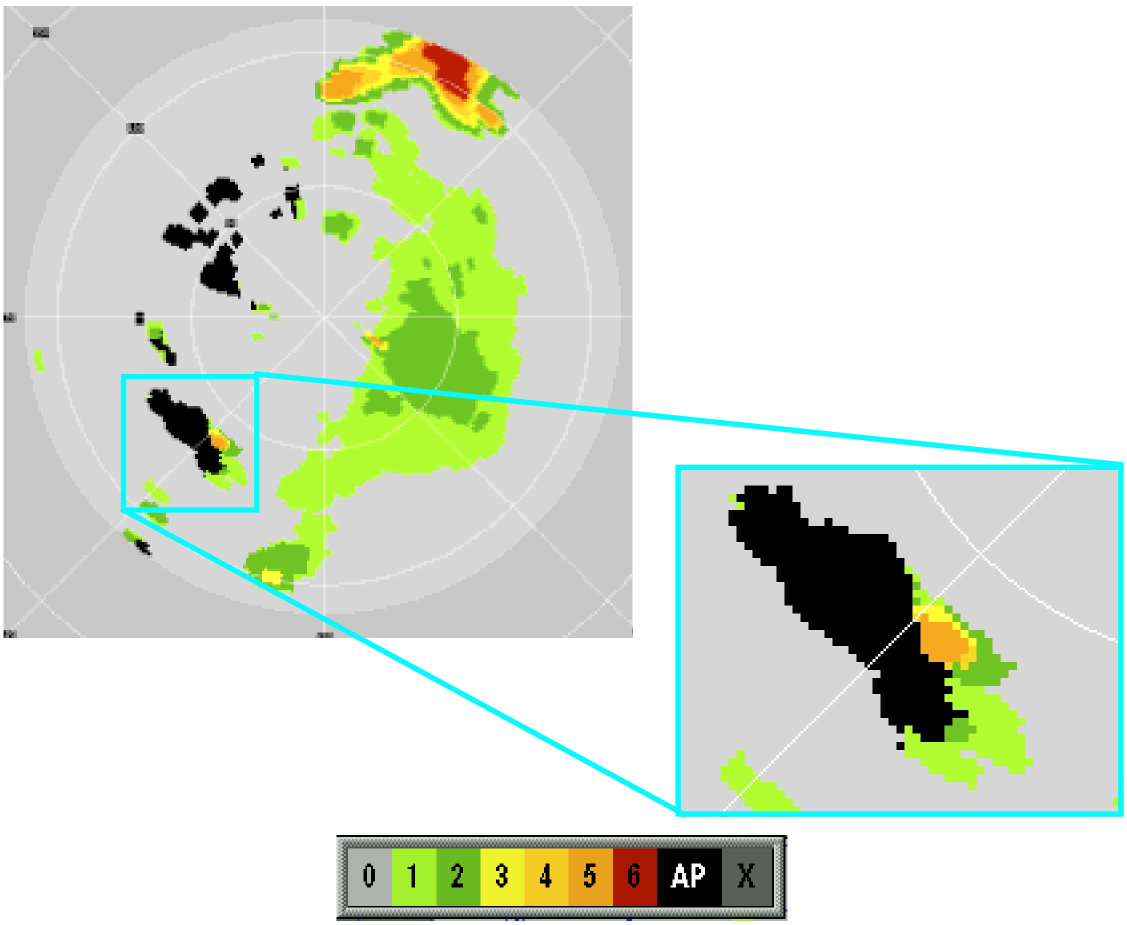

Figure III.7. Example of AP clutter breakthrough.

If the TRACON precipitation product is unavailable, the TDWR long range precipitation product (a 360-degree scan at an elevation angle of about 2.2 degrees with a maximum range of 45 nm from the TDWR radar and an update rate of about 5 minutes) is displayed as a fallback product.

The ASR-9-based products are updated every 30 seconds while the WSR-88D-based products are updated every one to 10 minutes and the 5-nm Precipitation product is updated every one to five minutes. The weather levels associated with the ASR-9-based precipitation products will probably differ from the weather levels in the other products where the products overlap because of the differences in the update rates and sensor characteristics. For example, the TDWR shows the intensity of precipitation at the altitude of the radar beam while the ASR-9 shows the intensity of the precipitation over the depth of the storm and the WSR-88D provides the maximum intensity in a vertical column above a point.

III.6 Operational Use

This product is a key product for improved traffic management and situational awareness within its coverage area. Since the TRACON Precipitation product does not replace the ASR-9 weather display on any controllers' displays, the Air Traffic Control (ATC) supervisor or traffic manager may use the AP-Flagged Precipitation product to indicate the location of AP clutter to any individual controller. The intensity of the precipitation can be used to identify areas of weather pilots are likely to avoid, aiding in the optimization of traffic patterns. In combination with storm motion and storm extrapolated position, this product can be used to determine when weather will impact ATAs, DTAs, terminal routes, and runways and when these impacts will end. This information can be used to maintain a higher effective capacity, improve safety, and reduce controller workload during thunderstorm conditions.

IV. 100-NM and 200-NM PRECIPITATION PRODUCTS

The 100-nm and 200-nm Precipitation products are representations of the location and intensity of weather as indicated by the WSR-88D system. An example of the 200-nm product is provided in Figure IV.1.

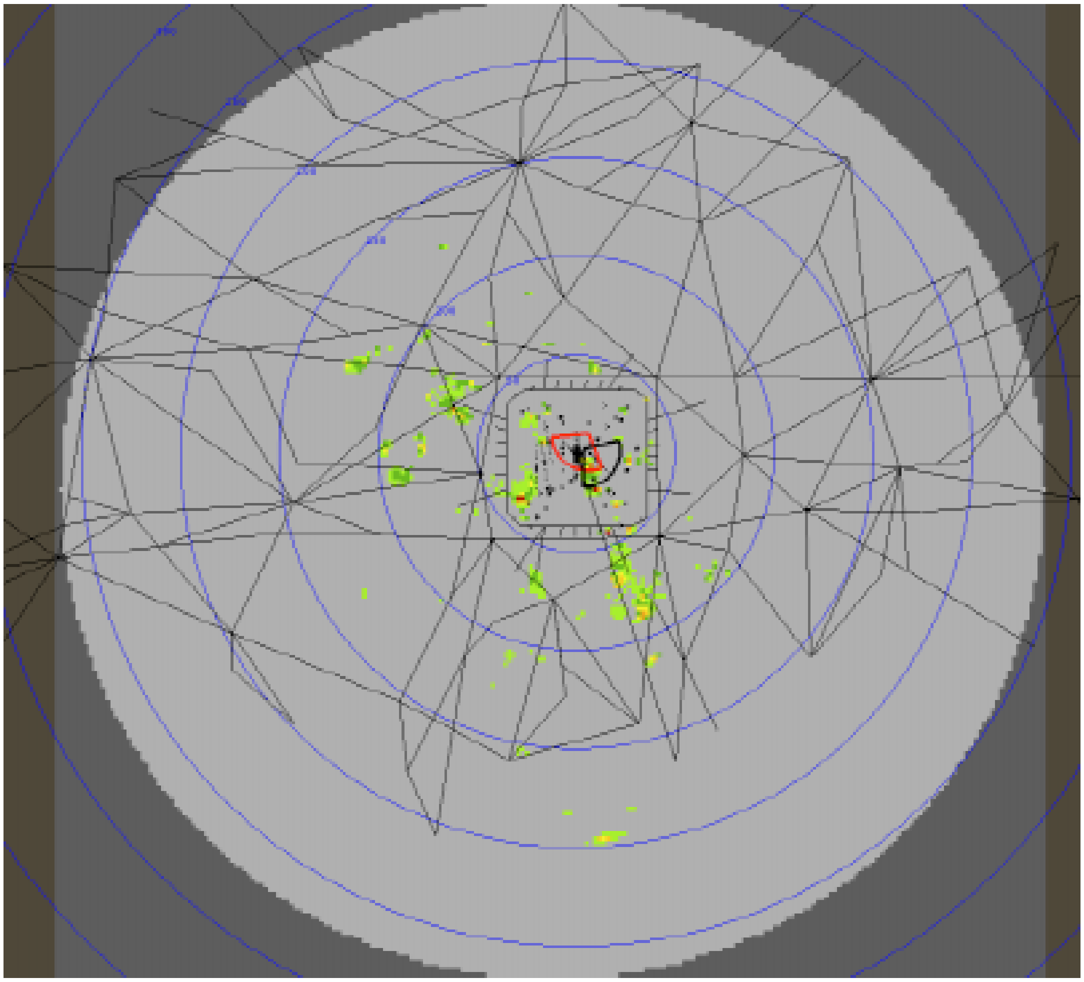

Figure IV.1. Example of the 200-nm Precipitation product.

IV.1 Product Generation

The 100-nm and 200-nm Precipitation products are the Composite Maximum Reflectivity products which are created by converting the radial data from each of the elevation scans to a grid and identifying the maximum reflectivity in the column above each grid point. These products are generated by the WSR-88D system and passed through to ITWS.

IV.2 Display Concept

WSR-88D-based products are provided in the standard NWS six-level representation. The levels are color-coded as shown in Figure IV.1; greens represent lighter precipitation, reds represent heavier precipitation. The user may choose which of the weather levels (one through six) are displayed in the SD graphics products windows. In addition, precipitation intensities below level one are represented by light gray and no data regions (areas where there is no coverage by the WSR-88D radar) are represented by dark gray.

The resolution of the 100-nm and 200-nm Precipitation products is 0.5 nm and 2.2 nm, respectively. The maximum ranges of the 100-nm and 200-nm Precipitation products are 100 nm and 200 nm, respectively, centered on the WSR-88D radar. The update rate is every five to ten minutes, depending on the radar scan strategy. During periods of no thunderstorm activity, the update rate may be as much as 10 minutes.

IV.3 Caveats

The WSR-88D-based products are updated every five to six minutes (when thunderstorms are present and depending upon the scan strategy) while the ASR-9-based products are updated every 30 seconds and the TDWR Precipitation product is updated every one to five minutes (depending on the scan strategy). The WSR-88D-based products will probably disagree with the weather levels in the other products, and between themselves, where the products overlap because of these differences in update rate, product resolution, and sensor characteristics. For example, the TDWR shows the intensity of precipitation at the altitude of the radar beam while the ASR-9 shows the intensity of the precipitation over the depth of the storm and the WSR-88D provides the maximum intensity in a vertical column above a point.

In general, there are no fallback products defined for the 100-nm and 200-nm Precipitation products. If unavailable, the associated windows will not display a precipitation product.

In two cases (New York and Chicago), two WSR-88D radars may provide products to the ITWS. In these cases, one radar is considered the primary and one is the secondary. If data from the primary WSR-88D radar are unavailable, the system can be manually switched (by a system administrator) to display data from the secondary WSR-88D.

IV.4 Operational Use

These products are key products for traffic management and situational awareness in the enroute airspace that surrounds a terminal area. The intensity of the precipitation can be used to identify areas of weather pilots are likely to avoid (aiding in optimization of traffic patterns) and provide awareness about storms that will move into the terminal area in the near future. In combination with storm motion and storm extrapolated position, these products can be used to determine when weather will impact ATAs and DTAs and when these impacts will end. This information can be used to maintain a higher effective capacity, improve safety, and reduce controller workload during thunderstorm conditions.

V. ITWS STORM MOTION PRODUCT

The ITWS Storm Motion Product provides an indication of the motion (speed and direction) of storms in the terminal area. The motion of storms is displayed by arrows (indicating direction) and alphanumerics (indicating speed). An example of the product is provided in Figure V.1.

Figure V.1. Example of the ITWS Storm Motion product.

V.1 Storm Motion Estimation

The Storm Motion product is computed for each precipitation product (i.e., the 5-nm, TRACON, 100-nm, and 200-nm Precipitation products). An image processing technique is used that compares two precipitation images which are separated in time. It is assumed that differences between the two images result solely from the motion of the weather; storm growth, evolution, and decay are not considered. Briefly, the method divides a radar image into overlapping local regions. Looking back through previous scans, the method correlates the weather in each region to find its most likely point of origin in the previous scan. Figure V.2 illustrates this spatial partitioning and full-grid analysis. The Storm Motion algorithm takes an area (highlighted region in Figure V.2a) and finds the best match for it in an earlier scan.This procedure is repeated using overlapping regions to construct a grid. For external display, the Storm Motion algorithm interpolates the grid to cells as illustrated in Figure V.2b.

The ability of the technique to compute motion is a function of the resolution of the input data and the speed of the weather. For example, the update rate of the TRACON precipitation map is 30 seconds, but storms do not move far enough in 30 seconds for the technique to compute an accurate motion. Storm motion estimates are computed from TRACON precipitation images that are separated in time by about five minutes. The spatial and temporal resolutions of the data limit the accuracy of the motion vectors to plus or minus 2.5 knots.

In convective situations, storm motion is often a composite of actual storm movement and any apparent motion that is due to growth and decay. For example, Midwest squall lines are usually observed to move from west to east. Individual storm cells move to the northeast within the squall line, with new cells developing at the southern end of the squall line and old cells dissipating at the

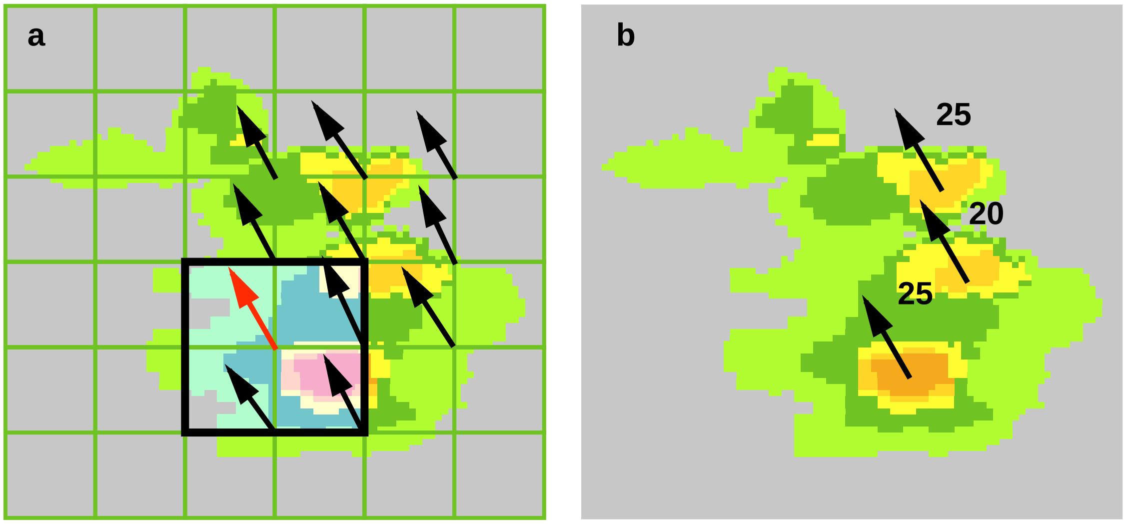

Figure V.2. Example of the generation of the Storm Motion product.

northern end. The storm motion vector for this situation might indicate movement to the east-northeast.

V.2 Display Concept

Storm Motion is indicated by constant-length, black arrows showing the direction of motion and accompanying text showing the storm speed in knots. Storm speeds are rounded to the nearest five knots. No motion arrows are plotted for storms with speeds of less than five knots; rather a black, unfilled square is used to indicate that the storms are nearly stationary. An example of this is provided in Figure V.1.

Storm Motion estimates are produced for all level three or greater weather and the vectors are assigned to the highest weather levels contained within the level three regions. The maximum range of the Storm Motion product is defined by the underlying precipitation product. The update rate of the products depends on the update rate of the underlying precipitation product, as shown in Table V.3.

Table V.3. Update rates for the Storm Motion products.

Product	Update Rate
5-nm	1 to 5 minutes, depending upon the scan strategy
TRACON	1 minute
100-nm	5 to 12 minutes, depending upon the scan strategy
200-nm	5 to 12 minutes, depending upon the scan strategy

Some of the storm motion arrows and extrapolated position contours are displayed automatically by the software based on some simple rules. The rules are stated in terms of the storm extrapolated position contours that are displayed. An example of these rules is provided in Table V.4. All storm motion arrows that associated with the displayed storm extrapolated position contours are displayed.

Table V.4. Rules for determining which extrapolated position contours (and thereby storm motion arrows) are displayed automatically.

Precipitation Product	Number and Location of Contours
5-nm	Display contours for all storms.
TRACON	1 storm within 10 nm of ARP
	2 storms between 10 nm and 20 nm of ARP
	2 storms between 30 nm and maximum range of ARP
100-nm	1 storm within 50 nm of ARP
	2 between 50 nm and maximum range of ARP
200-nm	1 storm within 50 nm of ARP
	2 between 50 nm and 100 nm of ARP
	2 between 100 nm and 200 nm of ARP

The user is able to select and de-select locations for which the associated Storm Motion and Extrapolated Position product associated with the nearest storm will be displayed. Using the middle mouse button, the user can enter the locations of storms whose storm extrapolated position lines and storm motion arrows will be displayed. The cursor location at the time of the click becomes a “location of interest” for the associated Storm Motion and Extrapolated Position product. The SD displays the storm extrapolated position lines and storm motion arrows for the closest storm (i.e., the storm whose centroid is closest to the location of interest) and whose storm extrapolated position lines and storm motion arrows are not yet displayed in the active graphics window. Every time the Storm Motion and Extrapolated Position product is updated, the SD recomputes the storms closest to the locations of interest.

The user can de-select user-selected storm extrapolated position lines and storm motion arrows using the right mouse button. If the nearest storm is one for which the storm extrapolated position lines and/or storm motion arrows are being displayed automatically, the SD displays an error message. If the nearest storm is one for which the storm extrapolated position lines and/or storm motion arrows are being displayed via user-selection, the SD removes the location of interest closest to the cursor from the list of locations of interest for the Storm Motion and Extrapolated Position product and the associated extrapolated position contours and storm motion arrows are removed from graphics window.

V.3 Caveats

Vectors associated with cells along the boundary of the precipitation map may not be reliable. Inaccuracies can result when distant storms first enter into the “field of view” of the precipitation map.

The 5-nm, TRACON, 100-nm, and 200-nm Storm Motion products may be quite different if the cell and envelope (*e.g.*, squall line) motions are different. For example, the resolution of the 200-nm Precipitation product is 2.2 nm and the update rate is five to six minutes when thunderstorms are present. The resolution of the TRACON Precipitation product is 0.5 nm and the update rate is 30 seconds. To produce valid results, the analysis pairs for the 200-nm product must be separated in time by at least 12 minutes; whereas the analysis pairs for the TRACON product are separated by five minutes. As a result of the differences in scale, the estimated 200-nm motion reflects the squall line motion more than the motion of the individual cells, which is typical of the TRACON product. The motion estimates are not incorrect; the features being tracked are different.

As a result of the application of the rules in Table V.4, the automatically displayed storm motion arrows will be different for each Storm Motion product.

V.4 Operational Use

This product is used for traffic management and situational awareness. When overlaid on the precipitation products and combined with the Storm Extrapolated Position product, Storm Motion may be used as a planning aid to better anticipate the need for runway and airspace configuration changes.The storm motion arrows show the direction and speed of the motion of the level three weather. This may be used to estimate the time of impact of heavy precipitation at ATAs, DTAs, and runways. Traffic managers can minimize the impact of weather on airport capacity, improve safety, and reduce controller workload by planning more effective traffic patterns and runway usage.

VI. ITWS STORM EXTRAPOLATED POSITION PRODUCT

Storm Extrapolated Position should be viewed as a supplement to the Storm Motion product (Chapter V). It provides leading-edge contours of cells or cell groups and extrapolates these contours to indicate the likely positions of these cells projected 10 and 20 minutes into the future. An example of the product is shown in Figure VI.1.

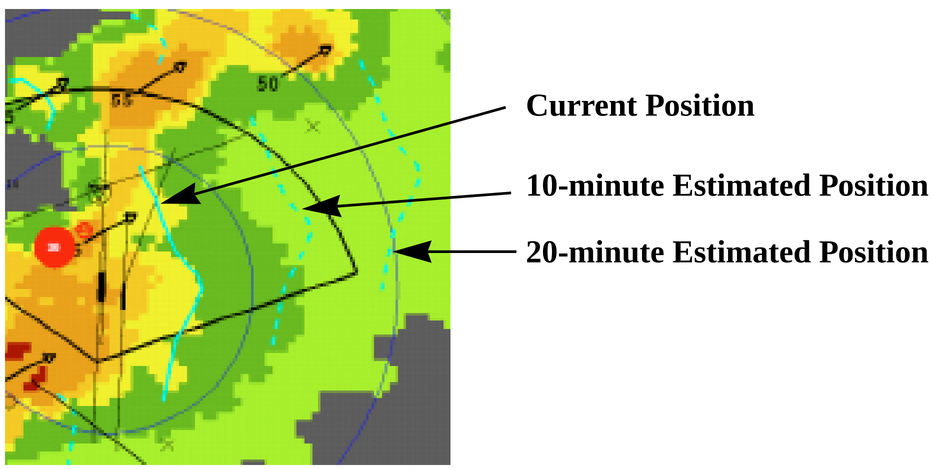

Figure VI.1. Example of the ITWS Storm Extrapolated Position product.

VI.1 Storm Extrapolated Position

The Storm Extrapolated Position product generation software uses each precipitation product (*i.e.*, the 5-nm, TRACON, 100-nm, and 200-nm Precipitation products) to identify areas of level three or greater weather. In addition, the algorithm interprets the internal motion grids computed by the Storm Motion algorithm. For each product, the Storm Extrapolated Position algorithm computes storm contours using NWS level three as its contouring level. Closely associated cells are first grouped, however, filling in and smoothing level three gaps of 2.5 nm or less. The internal Storm Motion grid is used to determine leading and trailing edges and only the leading edge of each contour is displayed. These contours are extrapolated 10 and 20 minutes into the future.

The accuracy of the product is directly dependent upon the accuracy of the Storm Motion algorithm. However, the error associated with extrapolation increases with increasing extrapolation time. In general, the 10-minute extrapolations will be about 95% accurate within plus or minus about one nautical mile of the actual weather 95 percent of the time. The accuracy of the 20-minute extrapolation depends on the growth and decay characteristics of the storms. For storms whose shape does not change significantly in 20 minutes, the 20-minute extrapolations are accurate approximately 85 percent of the time. For all storms (including those that grow and/or decay), the 20-minute extrapolations are accurate approximately two-thirds of the time.

VI.2 Display Concept

Following the display convention for gust fronts (Chapter VIII), three contours are displayed for each storm cell and/or storm cell group. The contours correspond to 0-, 10- and 20-minute extrapolations. The 0-minute (current location) contour is indicated by a solid blue line; the 10- and 20-minute extrapolations are indicated by dashed blue lines. In the case of Storm Extrapolated Position, a 0-minute contour is shown so that there will be no mistake regarding the association of contours and weather.

The update rate of the products depends on the update rate of the underlying precipitation product, as shown in Table VI.1.

Table VI.1. Update rates for the Storm Extrapolated Position products.

Product	Update Rate
5-nm	1 to 5 minutes, depending upon the scan strategy
TRACON	1 minute
100-nm	5 to 12 minutes, depending upon the scan strategy
200-nm	5 to 12 minutes, depending upon the scan strategy

Some of the extrapolated position contours and storm motion arrows are displayed automatically by the software based on some simple rules. An example of these rules is provided in Table VI.2.

Table VI.2. Rules for determining which extrapolated position contours are displayed automatically.

Precipitation Product	Number and Location of Contours
5-nm	Display contours for all storms.
TRACON	1 storm within 10 nm of ARP
	2 storms between 10 nm and 20 nm of ARP
	2 storms between 30 nm and maximum range of ARP
100-nm	1 storm within 50 nm of ARP
	2 between 50 nm and maximum range of ARP
200-nm	1 storm within 50 nm of ARP
	2 between 50 nm and 100 nm of ARP
	2 between 100 nm and 200 nm of ARP

The user is able to select and de-select locations for which the associated Storm Motion and Extrapolated Position product associated with the nearest storm will be displayed. Using the middle mouse button, the user can enter the locations of storms whose storm extrapolated position lines and storm motion arrows will be displayed. The cursor location at the time of the click becomes a “location of interest” for the associated Storm Motion and Extrapolated Position product. The SD displays the storm extrapolated position lines and storm motion arrows for the closest storm (i.e., the storm whose centroid is closest to the location of interest) and whose storm extrapolated position lines and storm motion arrows are not yet displayed in the active graphics window. Every time the Storm Motion and Extrapolated Position product is updated, the SD recomputes the storms closest to the locations of interest.

The user can de-select user-selected storm extrapolated position lines and storm motion arrows using the right mouse button. If the nearest storm is one for which the storm extrapolated position lines and/or storm motion arrows are being displayed automatically, the SD displays an error message. If the nearest storm is one for which the storm extrapolated position lines and/or storm motion arrows are being displayed via user-selection, the SD removes the location of interest closest to the cursor from the list of locations of interest for the Storm Motion and Extrapolated Position product and the associated extrapolated position contours and storm motion arrows are removed from graphics window.

VI.3 Caveats

The caveats associated with the Storm Motion product (Chapter V) apply here as well. Contours associated with cells along the boundary of the precipitation map may not be reliable. Inaccuracies can result when distant storms first enter into the “field of view” of the precipitation map.

The 5-nm, TRACON, 100-nm, and 200-nm Storm Extrapolated Position products will be different due to the scale differences noted in Section V.3. In addition, as a result of the application of the rules in Table VI.2, the default contours will be different for each Storm Extrapolated Position product.

It is important to emphasize that the product does not predict the occurrence of new cells. The product is relevant only for the extrapolation of cells that exist at the time of the current radar scan. Despite the display of 10- and 20-minute extrapolations, the product is not intended as an indicator of cell life span.

The algorithm currently does not take into account any effects due to storm growth and decay. Extrapolations may not be representative of future weather in situations where there are high rates of cell growth and/or decay.

Extrapolated position contours will not be available for storms whose leading edges are too short. In addition, extrapolated positions will not be drawn for storms whose speeds are less than a threshold value (*e.g.*, 10 knots).

VI.4 Operational Use

This product is a key product for traffic management and situational awareness. In combination with the storm motion and precipitation products, this product can be used as a planning aid to better anticipate the need for runway and airspace configuration changes.The extrapolated position contours provide an estimated time of arrival of level three weather. This may be used to estimate the time of impact of heavy precipitation at ATAs, DTAs, and runways. Traffic managers can minimize the impact of weather on airport capacity, improve safety, and reduce controller workload by planning more effective traffic patterns and runway usage.

VII. ITWS MICROBURST PRODUCTS

The ITWS Microburst algorithms are responsible for the detection and prediction of strong divergent outflows of wind near the ground surface generated from storm downdrafts. The detection and prediction portions of the product are actually separate algorithms whose outputs are combined into one set of display shapes and text messages. The purpose of this product is to enhance safety by providing warnings of potentially hazardous weather to landing and departing aircraft. The graphical alerts (shapes) are displayed on the SD. The text messages are displayed on the Ribbon Display at each tower controller position and in the Ribbon Display Alerts (Chapter X) window. These messages are read directly to pilots on final approach or departure. An example of the product as displayed in the graphics windows is provided in Figure VII.1.

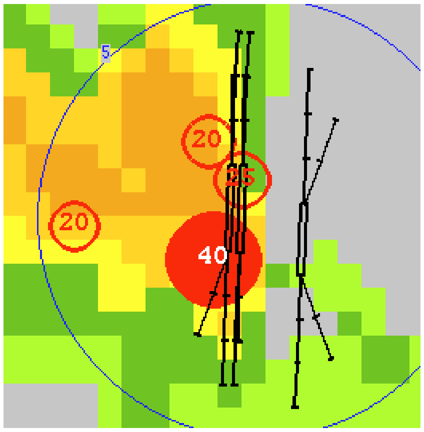

Figure VII.1. Example of the ITWS microburst detections on the SD.

VII.1 Microburst Hazard

The diverging outflow of cold air resulting from a strong storm downdraft can result in a rapid transition from a headwind to a tailwind for an aircraft encountering the event on takeoff or landing. The increased lift from the headwind can cause an unaware pilot to reduce speed and angle the aircraft nose downward, which accentuates the decreased lift on the tailwind side. When the microburst is strong and the aircraft is low, even an aware pilot may not be able to maintain safe flight. Most existing wind shear detection systems, such as the LLWAS and TDWR, warn about microbursts by specifying the anticipated change in wind speed (headwind to tailwind) along the flight path. The ITWS microburst detection algorithm has been improved to take advantage of recent studies by National Aeronautics and Space Administration Langley and several manufacturers of airborne wind shear detection systems. Microburst and wind shear severity are more closely related to the **rate** of the wind speed change (shear), rather than the magnitude of the change itself. This means that a 50-knot wind speed loss over distance of two nautical miles is inherently more severe than a 50-knot wind speed loss over a distance of four nautical miles. The use of shear, rather than wind speed difference, results in warnings which more closely reflect the danger to the aircraft.

VII.2 Detecting Microbursts

Each surface scan by the TDWR provides a picture of the component of the winds flowing toward or away from the radar. The ITWS microburst detection algorithm converts these Doppler velocities to a two-dimensional map of the shear along the path of the radar beams. The shear map is searched for regions of strong diverging shear (indicating winds at the surface are spreading - an important clue to microburst presence). The search is performed at several shear levels, and the areas of strong shear are analyzed for peaks to attempt to create one output shape per microburst event. The shapes are created as circles, unless the algorithm has strong evidence that the microburst event is not completely circular, in which case the TDWR-like "bandaid" shapes are output. Finally, the alerts are checked for precipitation on the ground or above the event to verify that enough moisture is present to cause a microburst. This helps remove false alarms created by other phenomena which may look like microbursts (such as a flock of birds taking off from the ground in all directions).

In previous experiments with the TDWR testing, microburst alerts equaling the maximum strength of each shape impacting the runway were displayed to the users. Users testing the system remarked about overwarning of microburst and wind shear severities. Now the microburst strength is downgraded based on the extent to which it overlaps the runway corridor. When an alert shape intersects a runway flight path, or is very close to it, the runway alert level is calculated by assuming that the strongest hazard is through the center of the event. The runway velocity change is then calculated by dividing the maximum length of the overlap of the alert with the runway corridor by diameter of the alert shape and multiplying by the maximum alert strength. This is depicted in Figure VII.2.

Fractional length overlap = $\dfrac{\textbf{1.0 nm}}{\textbf{1.5 nm}}$

Flight path strength = (1.0/1.5)*40 kts = 26.7 kts

Flight path strength = 25 kts (rounded)

Text Message:
18A WSA 25K- 1MF
(18 Approach, Wind Shear Alert, 25 knot loss at 1-mile final)

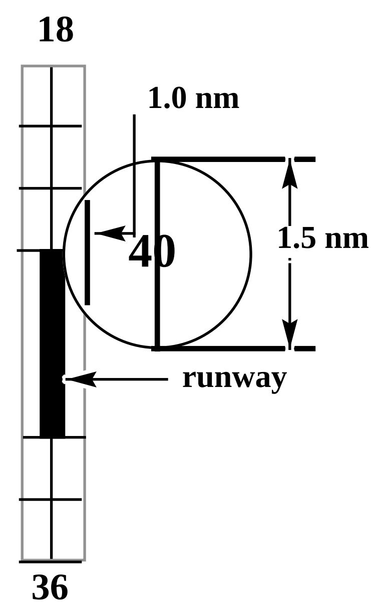

Figure VII.2. Strategy for the generation of a microburst alert.

VII.3 Predicting Microbursts

A microburst outflow forms as a thunderstorm downdraft reaches the ground and spreads out. Signs of this downdraft can be identified by the Microburst Prediction algorithm using TDWR precipitation data and temperature data from both surface observations and from commercial aircraft. Microburst predictions provide an average lead time of two to three minutes for developing microburst events. This provides a “heads up” to pilots lining up for final approach or takeoff and compensates for any latency in the Microburst Detection algorithm.

For each microburst prediction, a computer process checks to see if the prediction overlaps either a Wind Shear Alert (WSA) or a Microburst Alert (MBA). If no overlap occurs, a 15-knot WSA is issued. If the prediction does overlap a WSA, the WSA is upgraded to a 30-knot MBA. Finally, if a detected MBA is already present, no change is made to the display. With this concept, no new symbols are introduced on the SD and, if the predictions impact the runway corridors, both the controllers and pilots will be made aware of them through the Ribbon Display. They will appear as actual WSA or MBA messages.

VII.4 Display Concept

Microburst and wind shear outflow events are indicated on the SD by red outlines, as shown in Figure VII.1. The solid-filled shapes indicate **microbursts** with a maximum expected wind change of greater than or equal to 30 knots. Hollow shapes indicate **wind shears** with maximum expected wind changes of between 15 and 30 knots. The number inside the shape indicates the strength of the event. The nominal product update rate is every one minute and the maximum range is 16 nm from the TDWR.

If microburst or wind shear shapes overlap active runways in such a way as to produce microburst and wind shear warnings, the warnings are displayed on the controller Ribbon Displays and in the Ribbon Display Alerts (Chapter X) window on the SD. In addition, the ATIS Countdown Timer Product behaves as described in Chapter XIV.

At facilities where more than one TDWR system is present in the TRACON, the microbursts and wind shears depicted in the graphics windows represent a merger of the detections based on data from all TDWR systems. For example, the Dallas-Ft. Worth TRACON hosts two TDWR radar systems; one for the DFW airport and one for the DAL airport. In the graphics windows, the microbursts and wind shears from both systems will be displayed. However, the Ribbon Display will be driven by the detections based upon the data from the TDWR that is dedicated to the airport. Microburst detections from the DFW TDWR radar that overlap DAL runways will not be displayed on the DAL Ribbon Displays.

Special overlays known as hazardous sector overlays may be displayed in the graphics window. These overlays depict the perimeter of the microburst coverage region associated with a particular TDWR. If data from the associated TDWR are available to the ITWS product generator for generation of the Microburst product, the overlay is black. If data from the associated TDWR are unavailable to the product generator or the Microburst product is unavailable from the product generator, the overlay is red. An example of the hazardous sector overlays for a Dallas-Ft. Worth TRACON SD is provided in Figure VII.3. The data from the DAL TDWR are unavailable to the ITWS product generator so the overlay is red.

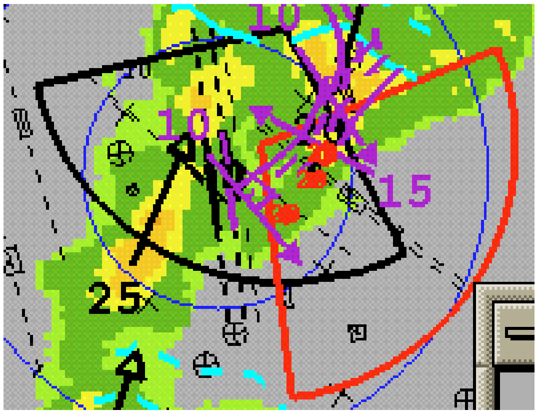

Figure VII.3. Hazardous sector overlays for a Dallas-Ft. Worth SD.

It is important to note that the hazardous sector overlays are not directly associated with the Ribbon Display Alerts product or the messages on the Ribbon Display. The hazardous sector overlays should **only** be used to evaluate the locations where microburst/wind shear shapes can appear, not areas where alerts will be generated. For example, even though the sector for the DFW TDWR covers the DAL airport, alerts will not be generated for DAL if the DAL TDWR is down.

Microburst and wind shear shapes are not displayed on the 100-nm and 200-nm Precipitation products.

VII.5 Caveats

The TDWR radar can only sense winds toward and away from the radar, along the beam. If a wind shear event has stronger wind components perpendicular to the radar beam than it does parallel to the beam, this cannot be directly sensed by the radar. This may result in a situation where the strength of the event is underestimated or the event may be missed entirely. In addition, the TDWR is a pencil-beam radar, indicating that its scans are performed over narrow spatial ranges. Situations may arise where the altitude at which the TDWR is viewing the microburst is substantially different than the altitude at which the plane will encounter the event. Since the strength of a microburst varies strongly with altitude, underestimation or overestimation of the hazard severity may result. Also, pilot reports of an encounter may be less than the issued alerts if the aircraft does not encounter the full loss of the microburst. However, it is **very rare** that a microburst will go undetected, especially the stronger, more hazardous microbursts.

The Microburst Prediction algorithm will not predict every microburst, nor will every prediction actually reach the 30 knots required to issue a microburst alert. Microbursts close to the edge of the TDWR sector, near the radar, or at very long range (greater than 16 nm from the TDWR) will not be predicted accurately. However, these regions typically are well away from the runways and approach and departure paths and therefore aircraft in these critical areas will not be impacted by this lesser accuracy.

VII.6 Operational Use

The primary goal of the microburst detection and prediction capability of the ITWS is to enhance safety. An aircraft encounter with a microburst or wind shear is potentially hazardous. If a microburst or wind shear is detected on or near the runways, a warning message is displayed on a controller's ribbon display. This warning is read directly to pilots.

The microburst and wind shear depictions on the SD also support planning. Detections are made within 16 miles of the TDWR in the TDWR coverage sector. Only those detections that impact runways and/or approach and departure corridors generate warnings that are displayed on the ribbon display. However, all detections are displayed on the SD. Using these detections and the Storm Motion (Chapter V) and Storm Extrapolated Position (Chapter VI) products, a traffic manager can identify if and when microburst activity may impact landing and departure operations, and when this activity might be expected to cease. Typically, pilots will avoid microburst encounters by not landing or departing, which in turn reduces airport capacity. By knowing when microburst activity is likely to occur, traffic managers can take steps to minimize the impact on operations.

VIII. ITWS GUST FRONT PRODUCTS

Like the corresponding TDWR product, ITWS gust front and wind shift products provide air traffic controllers and supervisors with timely reports of gust front location and strength, and provides planning guidance through forecasts of future gust front positions and expected wind shifts. In addition, gust fronts may contain wind shears that are potentially hazardous to landing and departing aircraft. Thus, the product also enhances safety of these aircraft. Unlike the initial TDWR product[1], the ITWS product uses state-of-the-art, knowledge-based image processing techniques to detect and track gust fronts in Doppler radar data. This technology provides more gust front detections (fewer misses), better quality detections (more of the gust front length is detected), and more consistent detections (better forecast capability) than the initial TDWR product. An example of the product is provided in Figure VIII.1.

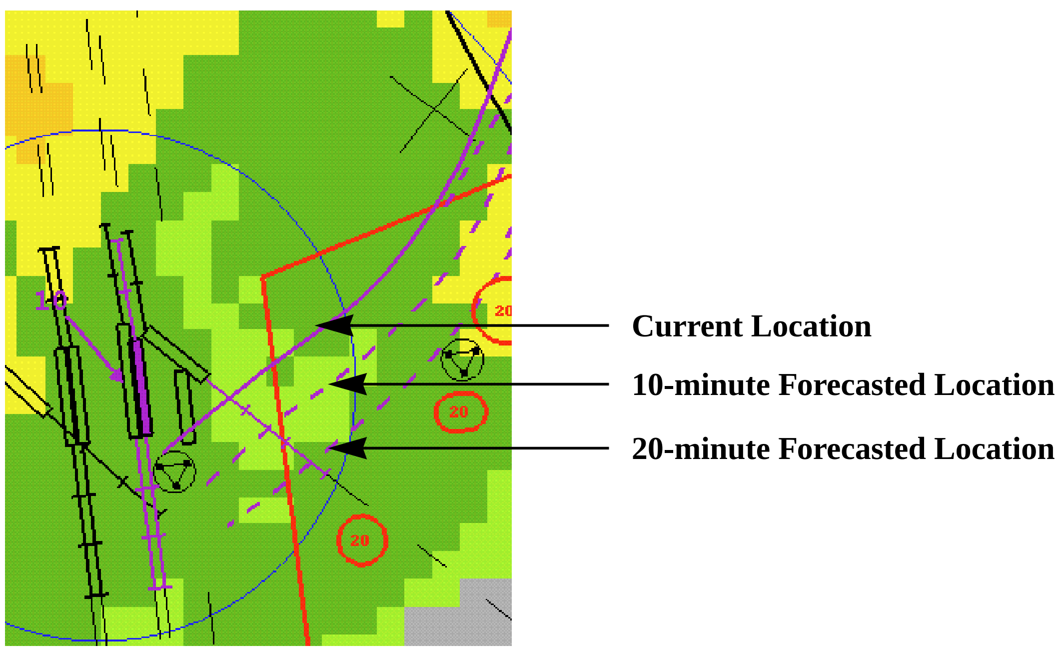

Figure VIII.1. Example of the ITWS Gust Front Detection product.

The ITWS Gust Front Impact Timer product provides an indication of the amount of time remaining until the most imminent of all gust fronts currently being tracked is expected to impact the airport. The Gust Front Impact Timer is in the Alerts Section in the upper right corner of the SD. The Alerts Section configuration for the one-airport case is shown in Figure VIII.2. The configuration for the more-than-one-airport case is shown in Figure VIII.3.

1.The TDWR program is deploying the key elements of the ITWS gust front and wind shift algorithm on an interim basis in an “outboard” processor attached to the TDWR computer.

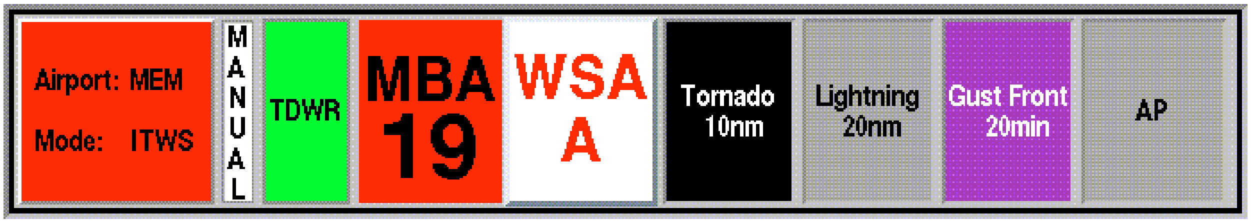

Figure VIII.2. Example of the Gust Front Impact Timer product for one airport.

Figure VIII.3. Example of the Gust Front Impact Timer product for the two-airport case.

VIII.1 Product Generation

The ITWS approach to gust front detection searches radar reflectivity and Doppler velocity data for several characteristic signatures in the data that may indicate the presence of a gust front. A number of feature detectors are used; one detects thin lines in a reflectivity image, another “subtracts” the previously processed reflectivity image from the current one and looks for motion, and another feature detector looks for lines of velocity convergence in the Doppler velocity map.

No single feature detector is a perfect discriminator in all situations; not all signatures are always present and other phenomena may mimic gust front signatures (such as migrating birds and thin bands of light precipitation). However, the combined opinion of a number of feature detectors provides a much more reliable confirmation of the presence of a gust front. The ITWS approach combines the evidence from all of the feature detectors.

Once the gust fronts have been detected, an attempt is made to associate each gust front with gust fronts contained in earlier images. A detection history is maintained to allow point-by-point correspondence and tracking of gust fronts. Propagation speed and direction are calculated for each associated point and are used to extrapolate the position of that point into the future to produce point-by-point flexible forecasts of future gust front position. For each gust front detection, a series of forecasts are generated for 1-minute intervals out to 20 minutes. For each detected front, the Doppler measurements in front of, within, and behind the front are examined to estimate the wind shear hazard and the wind shift associated with the front. LLWAS sensor data are also used where appropriate to improve gust front wind estimates in regions where Doppler measurements are ambiguous or absent (due to insufficient return signal).

The state of the Gust Front Impact Timer is computed each minute. The updated gust front detection and forecast locations are tested to determine if they overlap a shape designating the airport impact zone. If an overlap occurs, then there is at least one gust front within 20 minutes of the airport, and the timer activates. More specifically, the current locations of all detected gust fronts are tested for overlap with the airport impact zone. If any overlaps occur then the airport is currently impacted. If no detected gust fronts are impacting the airport, then the 1-minute forecast location of each gust front is tested for overlap. The process of testing all gust front forecasts for overlap is repeated for increasing forecast “horizon” until either an overlap is encountered or the maximum forecast horizon (nominally, 20 minutes) is reached. If a forecast overlap is encountered, then the corresponding forecast time represents the time to impact of the most imminent gust front, and the timer is activated. If no current gust front locations or forecasts (within 20 minutes) overlap the airport impact zone, then the timer is inactive.

VIII.2 Display Concept

Upon completion of processing, gust front detection information is sent to the SD for ATC use (Figure VIII.1). On the SD, the current gust front location is displayed as a solid purple line; dashed purple curves are used to display the 10- and 20-minute forecast positions. Behind each front the wind shift estimate is shown as a numbered arrow indicating the speed (in knots) and direction of the wind shift expected behind the front (not the propagation velocity of the front itself). Gust fronts can be quite extensive in length. Winds behind the gust front may vary in speed and/or direction along the length of the gust front. The displayed wind shift estimate for a gust front is an estimate of the winds behind the entire length of the gust front when the gust front is more than 20 minutes from the airport. When the gust front is within 20 minutes of the airport, the wind shift estimate represents an estimate of the winds behind the portion of the gust front that will impact the airport.

If the front crosses an active runway and the wind shear hazard exceeds 15 knots, an alphanumeric wind shear alert message is automatically generated and is displayed on controller Ribbon Displays for immediate dissemination to pilots for safety enhancement. The message is also displayed in the Ribbon Display Alerts window (Chapter X) and the ATIS Countdown Timer product behaves as described in Chapter XIV.

The gust front algorithm receives data and completes one iteration of processing approximately once every five to six minutes. In order to satisfy the need for more timely updates for fast moving gust fronts, an internal timer is used to regulate updates to the SD display at 1-minute intervals. In lieu of current detection reports from the algorithm, the gust front update routine substitutes appropriate forecast data from the most recent processing iteration and sends them to the SD. In this fashion, current and 10- and 20-minute forecast gust front positions are updated on the SD every minute.

Gust Front detections and forecasts are not displayed on the 100-nm and 200-nm Precipitation products.

When there is no gust front within a specified number of minutes (usually 20 minutes) of the airport, the Gust Front Impact Timer in the Alerts Section is gray. When one or more gust fronts are within the specified number of minutes of the airport, the timer turns purple with the expected time of arrival (in minutes) associated with the most imminent gust front in white. When a gust front is impacting the airport, the box is purple with the words “Gust Front” or “GF” in white in the center of the timer.

The gust front impact timer is recomputed and updated every minute.

VIII.3 Caveats

Generally, the ITWS gust front detection algorithm must “see” the gust front on two consecutive scans before issuing a detection. This requirement significantly reduces the likelihood of false alarms from unorganized, transient wind phenomena not associated with gust fronts (e.g., large-scale turbulence). However, depending on when the gust front forms during the radar scan sequence and accounting for algorithm processing time, this means that there can be a delay of approximately eight to 13 minutes in announcing the detection of a gust front that initially forms inside the 30 nautical mile coverage radius.

At facilities where more than one TDWR system is present in the TRACON, the gust fronts depicted in the graphics windows represent a merger of the detections based on data from all TDWR systems. For example, the DFW TRACON hosts two TDWR radar systems; one for the DFW airport and on for the DAL airport. In the graphics windows, the gust fronts from both systems will be displayed. However, the Ribbon Display, Ribbon Display Alerts product, and the Gust Front Impact Timer will be driven by the detections based on the data from the TDWR that is dedicated to a particular airport. Gust front detections from the DFW radar that overlap DAL runways will not be displayed on the DAL Ribbon Displays or in the DAL Ribbon Display Alerts window and the DAL Gust Front Impact Timer will not be activated.

If more than one gust front is expected to impact the airport within 20 minutes, the impact timer will display the minimum time-to-impact. There is no indication of which of the multiple gust fronts will impact the airport first, though it may be possible to determine this by examining the gust front detections and forecasts displayed in the graphics window.

VIII.4 Operational Use

Gust fronts may contain wind shears that are potentially hazardous to landing and departing aircraft. If such is the case, wind shear messages are provided to air traffic controllers to pass to pilots, thereby enhancing the safety of landing and departing aircraft. The gust front products also provide planning support. Gust fronts are often accompanied by changes in wind direction and/or speed that result in a runway reconfiguration. The gust front products can be used by traffic planners to determine if and when winds will change on the runways. If the change in runway configuration will result in a change in airport capacity, this product can assist air traffic managers match the air traffic demand to the airport capacity. Using this information, traffic planners can reduce the amount of time required to change runway configurations. This, in turn, reduces the period during which the airport capacity is diminished.

IX. ITWS STORM CELL INFORMATION PRODUCT

The ITWS Storm Cell Information product provides a textual description of storm attributes which cannot be deduced from the ITWS precipitation products alone. An example of the product is provided in Figure IX.1.

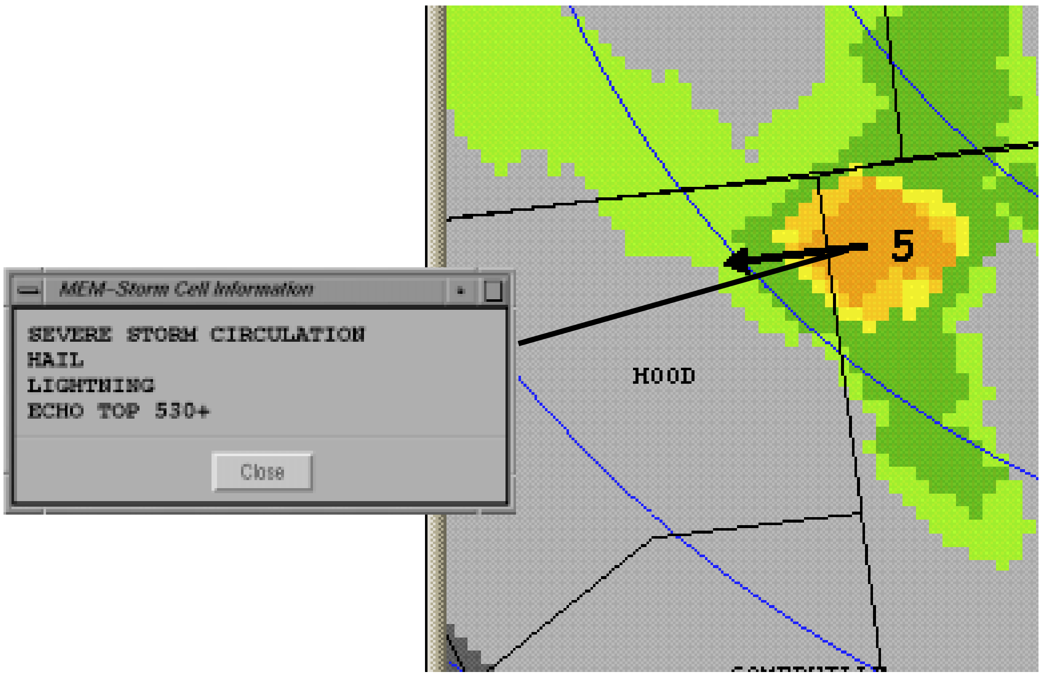

Figure IX.1. Example of the Storm Cell Information product.

IX.1 Generating Storm Cell Information

The generation of Storm Cell Information text is performed in three basic steps: storm cell identification, gridding of storm information, and text generation. Figure IX.2 shows a six panel display illustrating the generation of the product. A storm cell identification algorithm uses each of the ITWS Precipitation products (i.e., the 5-nm, TRACON, 100-nm, and 200-nm products) to create outlines of precipitation at levels three through six as shown in Figure IX.2a. Storm Cell Information data are determined within the highest precipitation level of a storm (maximum weather level of the storm cells in the overall storm). To account for some registration errors between the ASR-9 storm locations, lightning data, echo top estimates, *etc.*, the outlines are dilated by a specified distance (*i.e.*, 1.5 nm) as shown in Figure IX.2b.

Running in parallel to the storm cell identification algorithm is a gridding process. Mesocyclones and severe hail (greater than 3/4-inch diameter at the ground) detections from the WSR-88D radar are provided as point locations. Hail detections (defined as the probability of severe hail [POSH] greater than a threshold) are converted into areas (*i.e.*, are gridded) based on their association with high reflectivity cells from the WSR-88D data (Figure IX.2c). Mesocyclone detections are converted

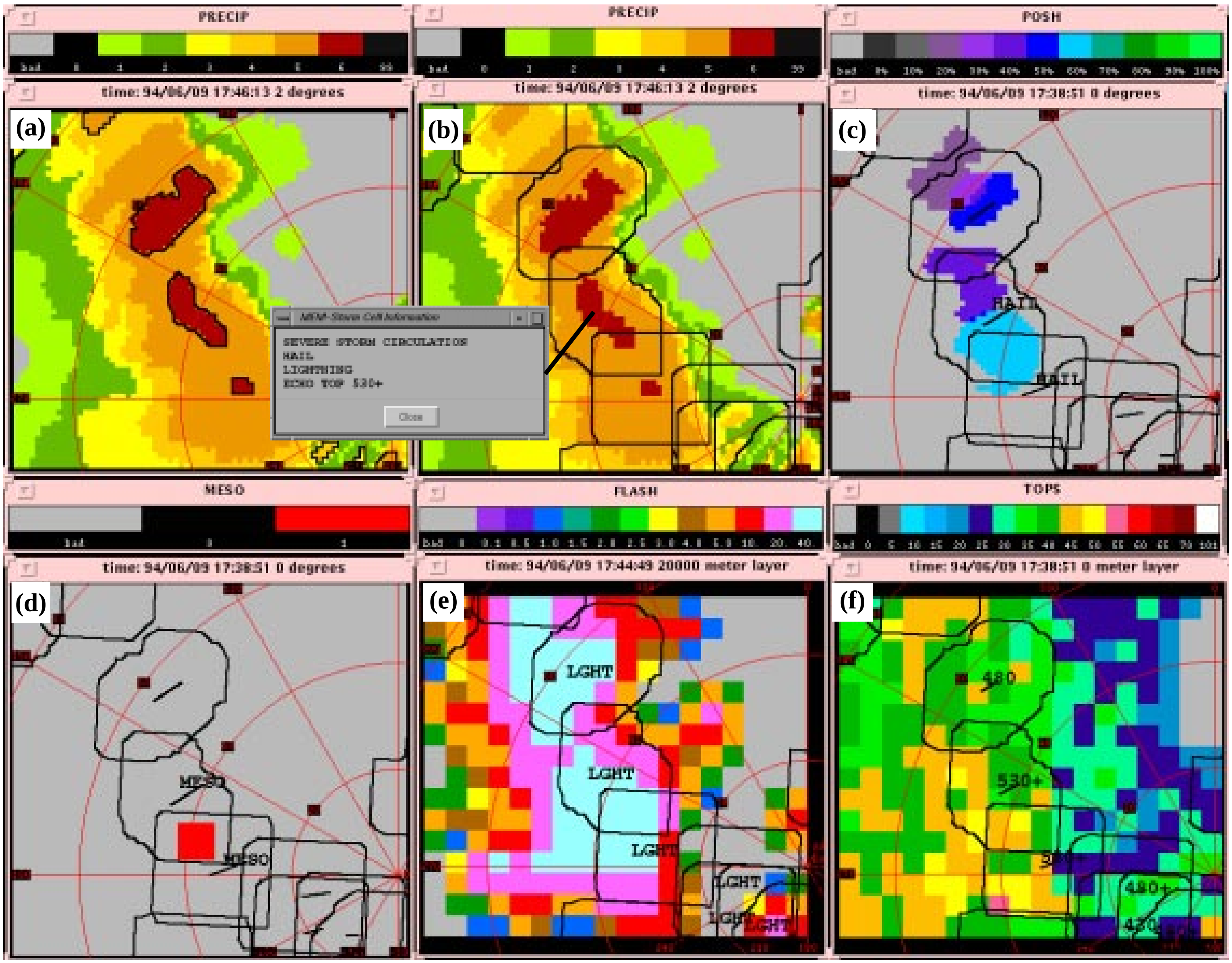

Figure IX.2. Example of how the Storm Cell Information product is generated.

to grids based on their physical size (Figure IX.2d). Cloud-to-ground lightning stroke detections are accumulated into a gridded image which depicts a two-minute average lightning flashrate (Figure IX.2e). The echo tops (in thousands of feet or kft) from WSR-88D are already provided in grid format (Figure IX.2f). Each of these grids is reoriented so it is centered on the ARP. Furthermore, these grids may be the result of data which, in the case of hail, echo tops and mesocyclones, are as much as six minutes old. Storm motion estimates from the ITWS Storm Motion product are used to compensate for motion that occurred over the age of the detections.

A final association process searches the area within an outline for sufficiently high levels of the other hazards. If the probability of severe hail, or if lightning flashrate is sufficient, a hail or lightning text message is added to the Storm Cell Information text box. If a mesocyclone is present, this is indicated as a “severe storm circulation” in the Storm Cell Information text box. Finally, the maximum echo top within the cell outline is reported.

IX.2 Display Concept

The Storm Cell Information text box appears when the user selects a location on the ITWS precipitation map. A line is automatically drawn from the text box to the storm cell closest to the location of the selection. The Storm Cell Information text box (Figure IX.1 and Figure IX.2) provides information about the storm cell to which the black line is drawn. When present, HAIL indicates a probability of the presence of severe hail at the ground of greater than a threshold (*e.g.*, 60%); LIGHTNING indicates a cloud-to-ground lightning flashrate greater than a threshold (*e.g.*, 0.2 flashes per 2 minutes) in the storm; ECHO TOP provides an estimate of the echo top of the storm above mean sea level in units of (x 100) feet; SEVERE STORM CIRCULATION indicates the presence of strongly rotating horizontal winds and strong updrafts in the storm.

The Storm Cell Information box will automatically disappear after 30 seconds. The update rate of the Storm Cell Information product depends upon the underlying precipitation product as shown in Table IX.1. If new precipitation and storm information data become available while the product is being displayed, the Storm Cell Information box will be updated with that new information. In addition, the line from the Storm Cell Information text box to the storm will move to reflect the location of the storm in the updated data.

Table IX.1. Update rates for the Storm Cell Information products.

Product	Update Rate
5-nm	1 to 5 minutes, depending upon the scan strategy
TRACON	1 minute
100-nm	5 to 12 minutes, depending upon the scan strategy
200-nm	5 to 12 minutes, depending upon the scan strategy

The product indicates if any of the components of the Storm Cell Information product are unavailable (*e.g.*, Hail: UNAVAILABLE). In addition, if the echo top estimate is taken from the highest elevation scanned by the WSR-88D, a “+” is appended to the estimate to indicate that the actual echo top may exceed the displayed value. This happens most often for storms that occupy the WSR-88D cone-of-silence (*i.e.*, the space immediately above the WSR-88D that is not scanned by the radar).

IX.3 Caveats

The primary potential algorithm pitfall comes from inaccuracies of the input data. This may mean that the lightning sensor provides an inaccurate lightning detection, or the severe hail or mesocyclone algorithms provide a false alarm. These systems have been thoroughly tested through other programs and are in general considered to be of high quality. Other potential error sources come from inaccuracies in the storm motion estimation. Data which are several minutes old may be located improperly, resulting in a lack of overlap with a cell outline. Given the high quality anticipated from the ITWS Storm Motion algorithm, this failure is believed to be unlikely.

The Storm Cell Information product provides information in the areas of the highest precipitation level in the storm. If mesocyclone (severe storm) or lightning detections fall outside those areas, they will not be reported in the Storm Cell Information text box.

IX.4 Operational Use

Storm Cell Information may be used for situational awareness and as an aid to planning traffic flow. The information contained in the Storm Cell Information product can be used to identify areas of weather that pilots are likely to avoid, aiding in the optimization of traffic patterns. The product also provides information on safety hazards associated with storms.

If the Storm Cell Information product indicates that a storm has a echo top of near zero, this is a strong indication that the WSR-88D is not sensing precipitation at that location. This may be a region of AP clutter (Section III.5).

X. ITWS RIBBON DISPLAY ALERTS PRODUCT

The ITWS Ribbon Display Alerts product provides on the Situation Display the alert messages that are displayed on the Ribbon Display (e.g., microburst, windshear, and tornado). An example of the Ribbon Display Alerts product is provided in Figure X.1. The alerts in this window might be found on the Ribbon Displays used by the tower controllers.

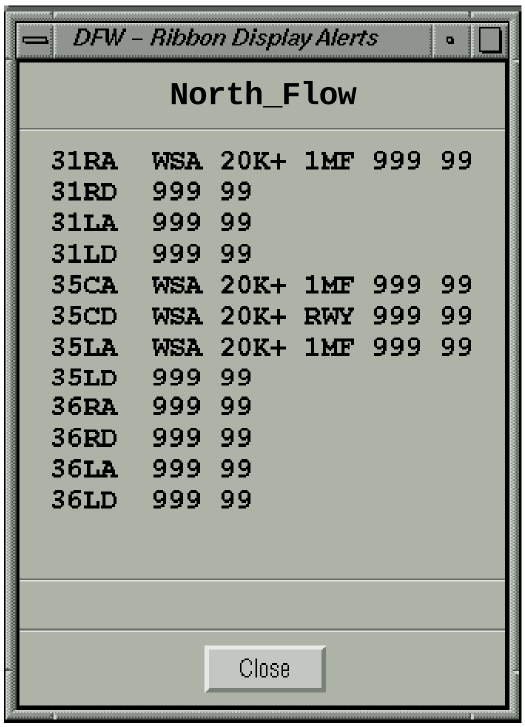

Figure X.1. Example of the Ribbon Display Alerts product.

X.1 Product Generation

Runway alerts are computed based on the overlap of the wind shear, microburst, or gust front shape with the runway corridor as described in sections VII.2 and VIII.2. When an ITWS is co-located with an LLWAS III system, both systems may produce alerts for the same region, resulting in the need to arbitrate between the systems. Arbitration of these alerts must occur to determine the appropriate message to be displayed on the Ribbon Displays. First the alerts are screened to remove unconfirmed alerts.

For loss alerts:

- Strong[1] microburst alerts from both systems are passed forward.

1.Definitions of “strong” and “weak” are site adaptable. Thresholds are site adaptable.

- Weak[1] microburst alerts from either system are passed forward unchanged if there is a loss above a threshold[1] from the other system; otherwise, the microburst alert is reduced to the maximum allowed wind shear alert.
- Strong[1] wind-shear-with-loss alerts from both systems are passed forward.
- Weak[1] wind-shear-with-loss alerts from either system are passed forward unchanged if there is a loss above a threshold[1] from the other system; otherwise the wind shear alert is dropped.

For gain alerts:
- Weak[1] wind-shear-with-gain alerts from either system are passed forward unchanged if there is a gain above threshold[1] from the other system; otherwise the alert is dropped.
- Strong[1] wind-shear-with-gain alerts from both systems are passed forward.

The screened alerts for the same region are then joined into a single alert.

For loss alerts:
- If both alerts are zero, the integrated alert is zero.
- If only one of the alerts is non-zero, the integrated alert is the location and strength of the non-zero alert.
- If both alerts are non-zero, the alert location is the location of the first encounter from either system and the strength is the strongest estimate of either the average of the two alerts, the weighted LLWAS estimate, or the weighted radar estimate. The value of the weights are site adaptable.

For gain alerts:
- If both alerts are zero, the integrated alert is zero.
- If only one of the alerts is non-zero, the integrated alert is the location and strength of the non-zero alert.
- If both alerts are non-zero, the integrated alert location is the location of the first encounter from either system and the integrated alert strength is the strongest estimate of either the average of the two alerts, the weighted LLWAS estimate, or the weighted radar estimate. The value of the weights are site adaptable.

The final step is to arbitrate any loss and gain alerts issued for the same region. If the loss alert for a region is at or above the microburst level, the final alert is the loss alert. If the loss alert is below the microburst level and the gain alert is enough stronger[1] than the lost alert, the gain alert is the final alert. If the gain alert is not enough stronger than the loss alert, the loss alert is the final alert for the region.

X.2 Display Concept

The Ribbon Display Alerts product is a listing of the microburst and windshear messages that appear on the Ribbon Displays. If microbursts and/or gust fronts overlap active runways in such a way as to generate warning messages, these messages are displayed in the upper portion of the Ribbon Display Alerts window as well as on the controllers' Ribbon Displays.

The formats of the messages in the text window are the same as the message formats on the Ribbon Displays. The Ribbon Display Alerts product update is a function of the update rates of the Microburst, and Gust Front algorithms. The Ribbon Display Alerts product updates as new information becomes available.

The highest priority source of Ribbon Display alerts is ITWS. TDWR data are processed by the ITWS product generator to generate Ribbon Display alerts. These are displayed both on the Ribbon Displays and in the Ribbon Display Alert text product window. If ITWS alerts are unavailable, the Ribbon Displays and Ribbon Display Alerts window automatically transition to the next available highest priority source of Ribbon Display alerts; TDWR. TDWR alerts are generated by the TDWR alert generation software. If TDWR alerts are unavailable, the Ribbon Display and Ribbon Display Alerts window will automatically transition to LLWAS III alerts (where possible). As higher priority alerts become available, the Ribbon Displays and Ribbon Display Alerts window will automatically transition to display those alerts.

X.3 Operational Use

The Ribbon Display Alerts product may be used for safety and situational awareness. When warning messages are in effect, many pilots will not land or depart. This reduces the airport capacity. Using the Ribbon Display Alerts product will allow traffic management specialists to get timely information on runway impacts. Additionally, all ITWS users will share situational awareness of the current runway winds.

XI. TERMINAL WEATHER TEXT MESSAGE PRODUCT

The Terminal Weather Text Message product shows ATC users the messages that are being delivered directly to aircraft via Aircraft Communications Addressing and Reporting System (ACARS) data link. These Terminal Weather messages provide a summary of the weather conditions around the airport based on the ITWS products displayed on the SD. **This product is not intended to be used directly by ATC personnel in the performance of their duties**, but is provided to ATC for shared situational awareness. This product allows ATC users to monitor the ITWS Terminal Weather messages being delivered to aircraft. An example of the product is provided in Figure XI.1.

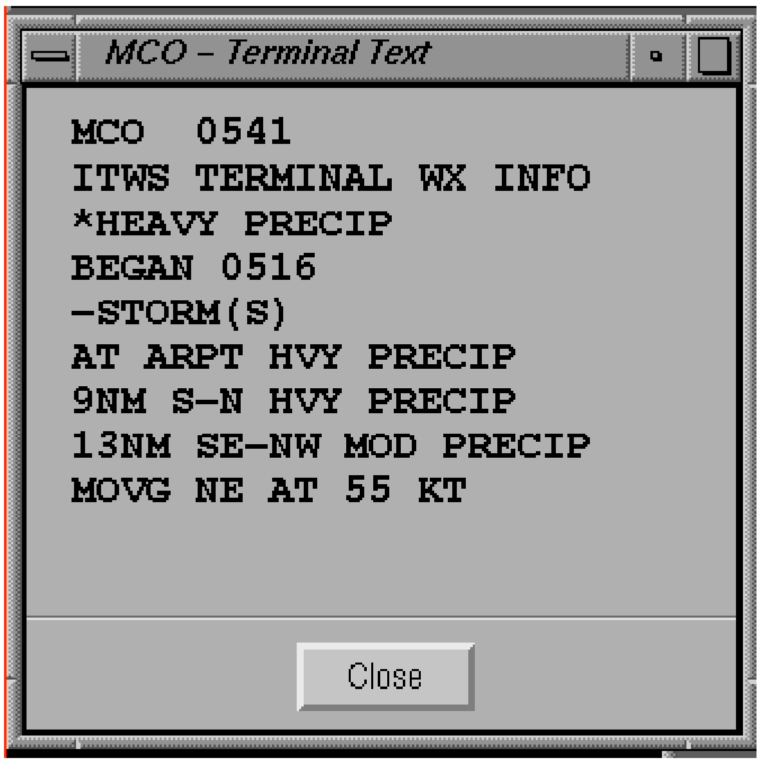

Figure XI.1. Example of the Text Message product.

XI.1 Product Generation

The Terminal Weather Text Message product is divided into three sections; Airport Impacts, Terminal Weather, and Expected/Previous Airport Weather. The Airport Impacts section is indicated by an asterisk (*) and lists the worst weather affecting any of the operational runways. For example:

*MODERATE PRECIP
BEGAN 2054

If a microburst is impacting one runway while heavy precipitation is impacting another runway, the text message product will issue information about the microburst (the most hazardous weather impacting the airport). The message would look like:

*MICROBURST ALERTS
30 KT LOSS
BEGAN 2105

The Terminal Weather section is indicated by a dash (-) and identifies the three closest storms to the airport. For each storm, the text message lists the minimum distance in nautical miles from the ARP to the level two weather, the direction of the storm from ARP, and the storm intensity based on the highest weather level in the storm (MOD for level two, HVY for level three and greater). The last line in this section states the average motion of all storms in the TRACON. An example of the Terminal Weather message is:

-STORM(S)	
APRT MOD PRECIP	(moderate precipitation at airport)
1NM W HVY PRECIP	(heavy precipitation one nautical mile west of ARP)
17NM N MOD PRECIP	(moderate precipitation 17 nm north of ARP)
MOVG E AT 9 KT	(moving east at nine knots)

The Expected Airport Weather section is indicated by a dot (.) and reports any expected precipitation or wind shift that will impact the operational runways. This section uses the precipitation and Storm Motion products to estimate the time at which the precipitation will begin on a runway. For wind shift, the product provides an estimate of the magnitude and time of the wind shift at the airport. The message will list the worst weather expected on the runways. For example, if moderate precipitation is expected on one runway and heavy precipitation is expected on another runway, the message will provide the information relative to the heavy precipitation. **This section does not attempt to predict wind shear or microburst activity**. An example of a message in the Expected Airport Weather section is:

.EXPECTED MOD PRECIP
BEGIN 2055

If no weather is found within 20 nm of the ARP, the text message is:

.NO STORMS WITHIN 20NM

If conditions warrant, a section reporting previous windshear activity or previous precipitation impacts will follow the .EXPECTED section. This section is preceded by a dot (.) and the label PREVIOUS. This section will be reported for a specified amount of time after the event has ended (nominally five minutes). An example of the Previous Airport Weather section is:

.PREVIOUS HVY PRECIP
BEGAN 1557 END 1601

XI.2 Display Concept

The Terminal Weather messages being sent to aircraft can be viewed by selecting the "Term Text" button located in the Product Status Buttons area of the SD (Figure I.2). When selected, a window appears that shows the text that ACARS-equipped aircraft are receiving. The messages are generated for weather within 20 nm of the airport and are nominally updated every minute under hazardous weather situations and every 10 minutes during "no-weather" situations.

XI.3 Operational Use

In an effort to reduce the controller workload involved in providing weather information to pilots, text-based terminal weather messages are being sent to aircraft via ACARS. The Terminal Weather Text Message provides the same information to ATC that pilots receive. The product is not intended for use by ATC personnel in the performance of their duties, but is provided to ATC for shared situational awareness.

XII. ITWS TERMINAL WINDS PRODUCT

The ITWS Terminal Winds product provides frequently updated (every five minutes) estimates of the horizontal wind at various altitudes for points of interest to ATC users (*e.g.*, at the arrival and departure gates and at turn-on to final approach). An example of the Terminal Winds product is provided in Figure XII.1.

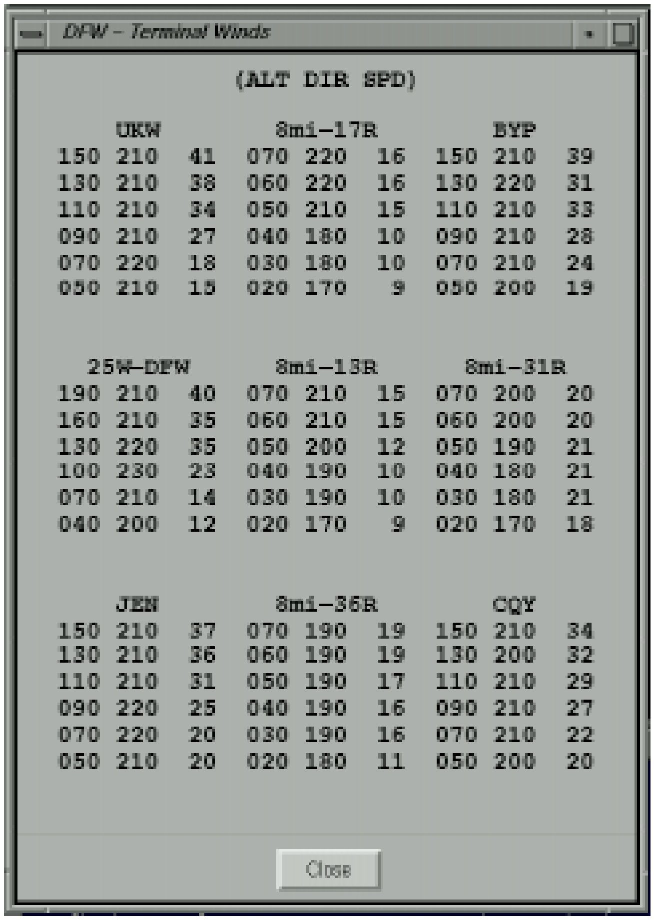

Figure XII.1. Example of the Terminal Winds product.

XII.1 Terminal Winds Estimation

Wind estimates are produced for two grids. The first grid has a horizontal resolution of about five nautical miles and a nominal vertical resolution of about 800 feet near the surface, increasing with altitude to about 1,800 feet at 30,000 feet. This product is generated for a region covering the TRACON plus 30 nautical miles, extending vertically to about 50,000 feet and with a nominal update rate of every 30 minutes. The primary sources of data for the first grid are the Meteorological Data Collection and Reporting System (MDCRS) reports from commercial aircraft arriving and departing the airport and the National Centers for Environmental Prediction Rapid Update Cycle (RUC), a weather forecast model.

The second grid is nested in the first. It has a horizontal resolution of one nautical mile and the same vertical resolution as the 5-nm resolution grid. The second grid covers a nominal 65-nm x 65-nm region centered on the ARP, extends vertically to about 18,000 ft and is updated every five minutes. The horizontal extent of this product is site specific and depends on the expected region of TDWR and WSR-88D coverage. The primary sources of data for the 1-nm product are the Doppler data provided by the TDWR and WSR-88D weather radars and the 5-nm resolution analysis grid.

The full set of data sources used to compute wind estimates for the Terminal Winds product are:

- RUC - a national weather forecast model with a 20-nm horizontal resolution and one hour update rate. The update rate is slow relative to the update rate for the Terminal Winds product. However, since RUC is a forecast model, forecasts of the winds can be used to provide current estimates of the wind to fill in regions without current measurements.
- TDWR Doppler radar - measurements of the components of the wind toward and away from the radar with a 480 ft range resolution and a five-minute update rate.
- WSR-88D Doppler radar - measurements of the components of the wind toward and away from the radar with a 0.54-nm range resolution and a six-minute update rate.
- MDCRS Aircraft measurements - measurements of the wind speed and direction taken at random points and times along flight paths, with a data latency of at least five minutes, and often significantly longer.
- LLWAS - six to 20 measurements of the wind speed and direction at the airport surface with a 1-nm to 1.5-nm horizontal resolution and a 10-second update rate.
- Automated Surface Observing Stations (ASOS) - widely spaced vector measurements at the surface with rapid update rate.

The Doppler radars provide accurate and dense measurements in regions with enough reflectors (for example, precipitation and/or bugs and dust) for the radars to gather returns. This limits the vertical extent of dense Doppler data on most clear summer days to 7,000 ft or less in the summer. In the dry clear air of the winter, the vertical extent of good Doppler return will be even lower. Doppler radars are also limited to measuring only the component of the wind either towards or away from the radar. That is, if the radar is looking due north and the wind is from the west, the radar will measure the north component of the wind, which is zero. The radar correctly measures the north component but does not provide information, at that point, on the west component. The west component must be derived from other data sources, including another Doppler radar.

XII.2 Winds Estimation

The ITWS Terminal Winds receives data from a numbers of sources which provide information of differing content, update rate, and quality. The analysis must properly assemble these data to provide accurate estimates of the wind at each point of the analysis grid. This is done in a two step cascade-of-scales process. At each step, finer resolution wind estimates are computed using a least squares statistical technique to minimize the errors in the final wind estimates. Figure XII.2 shows the data flow for this process.

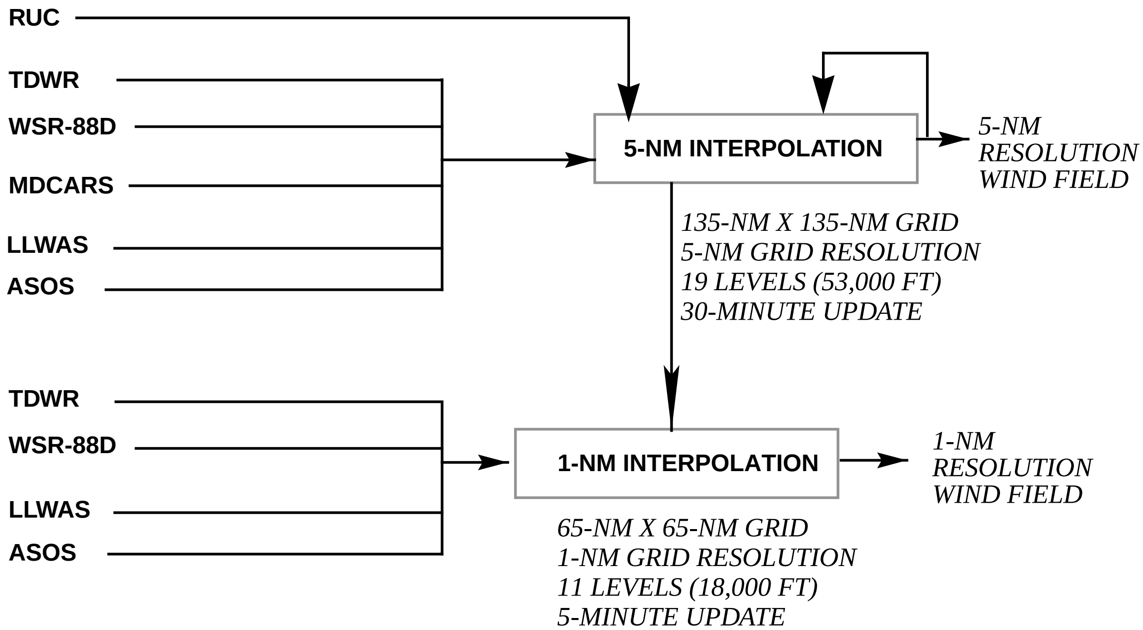

Figure XII.2. Data flow for Terminal Winds.

The first step in the cascade-of-scales is to compute the 5-nm resolution product. The RUC wind forecasts are interpolated to the 5-nm grid and then refined using all of the available data. This is done every 30 minutes.

The second step is to compute the 1-nm resolution product. In this step, the current 5-nm product is interpolated to the 1-nm grid and then refined using only the rapid update data (that is, Doppler data and automated surface observations) every five minutes.

XII.3 Display Concept

The Terminal Winds product is created by extracting the winds at the altitudes and locations specified by the user from the gridded wind field. The data are presented as a table containing various locations of interest to ATC (Figure XII.1). Under each location (e.g., arrival and departure gates) are three columns: the first is altitude (x 100 feet) above MSL, the second is wind direction in degrees rounded to the nearest 10 degrees, and the third is wind speed in knots computed at the given altitude. If the product generation software determines that the wind estimates are not reliable (using a statistical approach), the direction and speed estimates are replaced in the table by nines (e.g., 999 999). The data in the table are updated every five minutes.

There is a separate Terminal Winds product for each airport associated with the SD. The altitudes and locations for one airport may be different than those for another airport.

XII.4 Operational Use

The Terminal Winds product has been used by air traffic managers for traffic management and situational awareness. Observations at the Prototype ITWS Field Site at Dallas-Ft. Worth has identified meteorological conditions during which merging and sequencing of aircraft is problematic. These conditions and the resultant problems are provided in Table XII.1.

Table XII.1. Meteorological conditions leading to problems with merging and sequencing of aircraft at DFW.

Meteorological Condition	Aircraft Response	Result
Strong northwesterly wind (greater than 60 knots) at the Northwest gate	Aircraft approaching from the northwest to have a much higher ground speed than those approaching from the southwest	Difficulties when merging flow from the west
Easterly winds at arrival gate	Aircraft at the northeast gate (busiest at DFW) have tail-wind	Loss of time for adjustments to final leg and difficulties in merging with traffic from southeast gate
Strong south wind between 2000 and 5000 feet	Following aircraft overtake leading aircraft	Difficulty in merging northwest and southwest arrivals on base leg and compression from base leg to final leg when landing south and d
Shallow layer of north winds after frontal passage that deepens with time	Following aircraft overtake leading aircraft	Compression on final approach leg

Prior to having the ITWS Terminal Winds product, the traffic manager might have increased spacing between arriving aircraft unnecessarily to compensate for these meteorological conditions. This would result in a loss of capacity. The Terminal Winds product shows the traffic manager winds at various altitudes throughout the TRACON, allowing more precise spacing of aircraft. Uncommon wind speeds or directions aloft can also cause inefficient aircraft spacing or descent profiles, and better knowledge of the winds can be used to improve air traffic control efficiency.

For the initial ITWS deployment, the Terminal Winds information will be used also by the Center TRACON Automation System and the ITWS gust front detection. Future applications for this information include the ITWS Convective Weather Prediction product.

XIII. RUNWAY CONFIGURATION PRODUCT

The ITWS Runway Configuration product shows the runway configuration in use a particular airport and how runways are assigned to Ribbon Displays. An example of the Runway Configuration product is provided in Figure XIII.1.

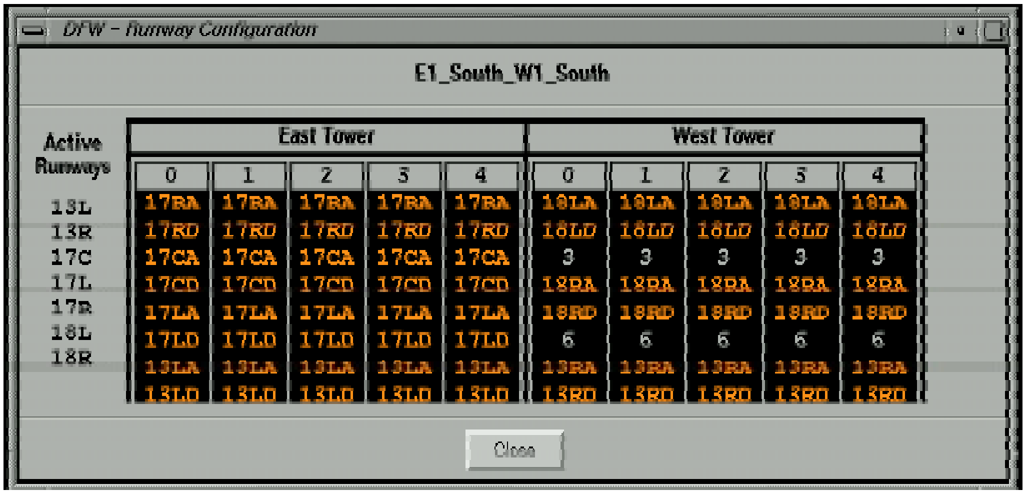

Figure XIII.1. Example of the Runway Configuration product.

XIII.1 Display Concept

At the left of the Runway Configuration product window is a list of active runways. The right side of the window shows each Ribbon Display associated with the airport and shows which runways are assigned to which lines of the various Ribbon Displays.

XIII.2 Operational Use

The Runway Configuration product is used by traffic planners to determine which runway configuration is in effect at a particular airport. This is particularly useful for users who do not have direct access to the Ribbon displays, as in a complicated airspace like New York with three major Air Route Traffic Control Centers providing aircraft to the TRACON.

XIV. ATIS COUNTDOWN TIMER PRODUCT

The ATIS Countdown Timer provides guidance to ATC personnel for changing the Automatic Terminal Information Service (ATIS) messages. The product indicates when microburst and wind shear advisories should be issued on the ATIS and when such advisories should be removed, in accordance with established Air Traffic procedures. An example of the product is provided in Figure XIV.1. The boxes labeled MBA and WSA in the Alerts Section of the SD change color to indicate that ATIS microburst and wind shear advisories should be issued and provide countdown timers to indicate when ATIS microburst and wind shear advisories should be removed. There are ATIS timers for each airport associated with the ITWS product generator.

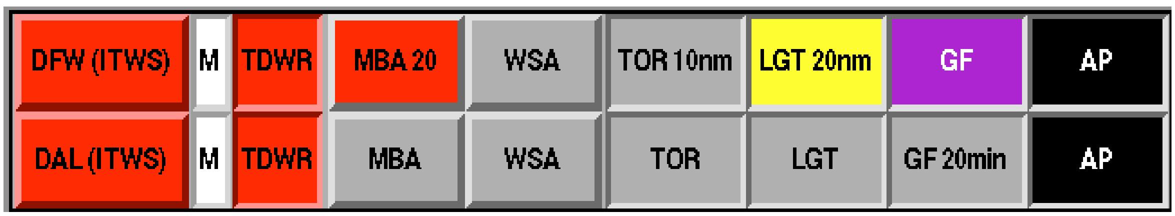

Figure XIV.1. Example of the ATIS Countdown Timer product.

XIV.1 Product Generation

In accordance with established Air Traffic procedures, ATIS messages are required to include microburst and wind shear advisories when those alerts are being, or have been, issued at an airport. The ATIS Timers are initiated in two ways: 1) automatically based on Ribbon Display messages and 2) manually by the user to support pilot reports (PIREPs). When an automatic alert is issued on the Ribbon Displays or when a PIREP is received and input, the ATIS message is updated to include “Wind shear advisories in effect.” For PIREPs, this message remains on the ATIS for 20 minutes. For automated alerts, this message remains on the ATIS for 20 minutes after the last message disappears from the Ribbon Display. The process for microburst alerts is similar except that the ATIS message is “Microburst advisories in effect.”

If a PIREP of wind shear or microburst is received and the SD is configured to support PIREPs, the ATC user may select the appropriate box (MBA or WSA) with the left trackball button. This selection changes the color of the box (if the box is gray) and resets the countdown time to the appropriate time interval. If a countdown is in progress, selecting the box will reset the timer to 20 minutes. If an error is made in submitting a PIREP, the PIREP may be withdrawn (from the initiating SD) by clicking the right trackball button on the appropriate box.

Whether initiated automatically or manually, the data about the status of ATIS timers are sent to the ITWS product generator for distribution to all SDs that are configured to display the Alerts Section for the particular airport. In this way, the ATIS timers on all SDs configured to display information for that airport show the same information.

XIV.2 Display Concept

The Countdown Timer will activate automatically when wind shear or microburst alerts are being issued on the Ribbon Display. Thus, it will only activate when microbursts or wind shears are impacting ARENAs (runway, 1 to 3 mile final, 1 to 2 mile departure, etc.) for active runways that are assigned to a Ribbon Display. At SDs that are configured to support PIREPs, an ATC user may activate the Countdown Timer product (*e.g.,* in response to a PIREP) by selecting the MBA and/or WSA boxes. The update rate of the product is every 30 seconds.

When alerts are active the MBA and WSA boxes change colors. When an automated microburst alert is displayed on the Ribbon Display, the MBA box turns red to indicate that an ATIS microburst advisory should be issued. Similarly, the WSA box turns white when a wind shear alert is displayed on the Ribbon Display to indicate that a wind shear advisory should be issued. As long as wind shear and/or microburst alerts are displayed on the Ribbon Display, the MBA box will be red and the WSA box will be white.

To support the removal of ATIS microburst and/or wind shear advisories, a countdown timer is provided in the MBA and WSA boxes. When microburst alerts disappear from all Ribbon Displays, a countdown timer starts in the MBA box showing the time remaining until the message is to be removed. The same is true for wind shear alerts. In the example shown in Figure XIV.1, there are 20 minutes remaining before the microburst message is to be removed from the ATIS. When the countdown timer reaches zero, the box turns gray and the timer disappears (*i.e.*, it reverts to the unalerted state).

If the SD is not configured to support PIREPS and the MBA and/or WSA buttons are selected, an error message is displayed.

XIV.3 Caveats

The ATIS timers are activated by wind shear and microburst messages that appear on the Ribbon Display. At facilities where more than one TDWR system is present in the TRACON, the microbursts and wind shears depicted in the graphics windows represent a merger of the detections based on data from all TDWR systems. For example, the Dallas-Fort Worth TRACON hosts two TDWR radar systems; one for the DFW airport and on for the DAL airport. In the graphics windows, the microbursts and wind shears from both systems will be displayed. However, the Ribbon Display, and therefore the ATIS timers, will be driven by the detections based on the data from the TDWR that is dedicated to that airport. Microburst detections from the DFW radar that overlap DAL runways will not be displayed on the DAL Ribbon Displays and will not drive the DAL ATIS timers.

PIREP submissions will not be accepted if there is a problem with the generation of microburst or wind shear alerts.

XIV.4 Operational Use

The ATIS timers are used to aid the management of the recorded ATIS messages. They also provide shared situational awareness of pilot-reported wind shear that may not be depicted in the graphics portion of the ITWS SD.

XV. TORNADO PRODUCT

The Tornado Product shows the location on the SD of all tornadoes within 200 nm of the WSR-88D. The tornado is depicted as a black triangle circumscribed by a hollow black circle, as shown in Figure XV.1. If a tornado is determined to be within a specified distance (for example, 10 nm) of the ARP, a box in the Alerts Section of the SD turns black with white text and a message appears on the Ribbon Display and in the Ribbon Display Alerts product (Chapter X) window. An example of a tornado alert is shown in Figure XV.2.

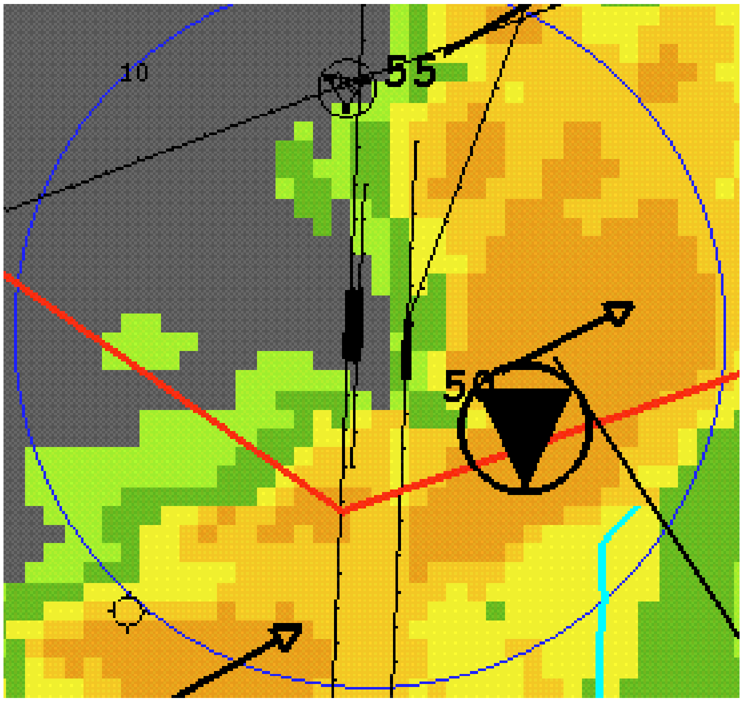

Figure XV.1. Example of a tornado detection near the Orlando International Airport.

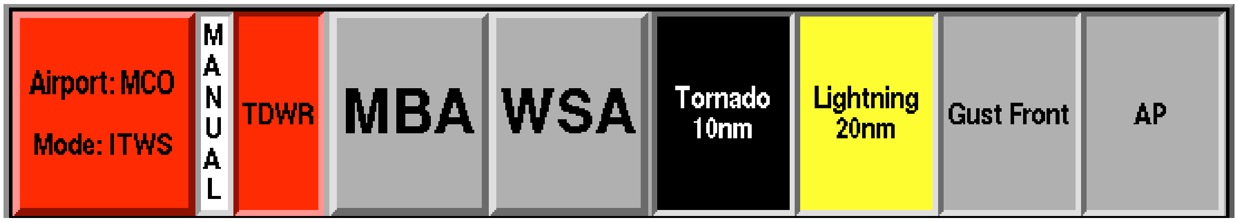

Figure XV.2. Example of the Tornado Alert product in the Alerts Section.

XV.1 Tornado Detection

The Tornado Detection Algorithm uses radial Doppler velocity data from the WSR-88D radar to determine the presence of tornadoes. On a given radar sweep, the azimuth-to-azimuth velocity difference at a specified range from the radar is computed. These adjacent velocity differences indicate shear that may be associated with a tornadic circulation. If the difference exceeds a threshold value, the location is stored as a radial feature. This search of the radial data is performed on all sweeps of the pencil beam radar.

Three or more radial features from a given sweep are combined, based on proximity, to create a two-dimensional feature. Two-dimensional (2-D) features are saved if their length-to-width (aspect) ratio is less than four.

Two-dimensional features are combined to create three-dimensional (3-D) features. First, the 2-D features are sorted according to increasing height (Figure XV.3). Three elevation scans from the WSR-88D radar are shown to indicate how the radar transects the tornado. As the radar scans higher elevation angles, the altitude of the detected features increases.

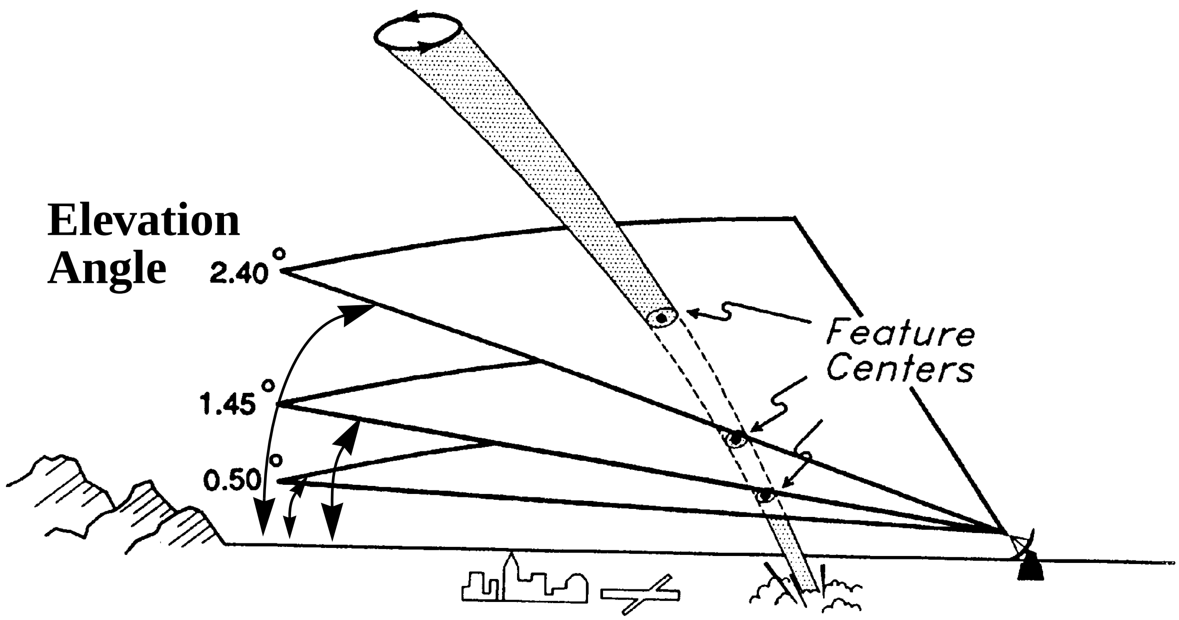

Figure XV.3. Example of 2-D features combined to create a tornado detection.

Next, locations of 2-D features are compared. The location of the lowest 2-D feature is compared with the location of the next lowest 2-D feature. If they are at most about 1.5 nm apart in the horizontal, they are associated into a 3-D feature. This process continues until the highest 2-D feature has been considered. The process is repeated with the lowest feature that has not been associated and the process ends once all possible associations have been made. A tornado detection is declared if a 3-D feature consists of at least three 2-D features and if the lowest feature is contained in the lowest elevation angle.

XV.2 Display Concept

Tornado detections are indicated on the SD by a filled, black triangle circumscribed by a circle. When an estimate of the motion of the tornado is available, the triangle points in the direction of motion and a white number in the center of the triangle indicates the speed. When no motion estimate is available, as shown here, the triangle points down. This icon is displayed for all precipitation products (*i.e.*, 5-nm, TRACON, 100-nm and 200-nm). If a detection occurs within a specified distance (*e.g.*, 10 nm) of the ARP, a message is displayed on the Ribbon Display and in the Ribbon Display Alerts window that indicates the direction from the ARP to the tornado detection (*e.g.*, TORNADO SW). The update rate of the product is about five to six minutes, depending upon the WSR-88D scan strategy.

XV.3 Caveats

Although the tornado product issues very few false alarms, any velocity-based algorithm is highly dependent on the quality of the velocity product. False alarms may occur if Doppler velocity estimates are erroneous. In addition, a number of false alarms may occur due to small, shallow circulations along the gust fronts that precede squall lines.

The Tornado Detection Algorithm suffers from a “detection range” deficiency. Detection ability decreases with increasing range, especially for the weaker tornadoes. Examples of these types of tornadoes include the “landspout” tornadoes that often occur in the High Plains environment, as well as tornadic circulations along thunderstorm gust fronts (referred to as gustnadoes). These weaker tornadoes may only be detected within a range of about 20 nm.

XV.4 Operational Use

This product may be used to plan air routes that will keep aircraft away from tornadoes near the airport and to warn ATC personnel to take appropriate actions. The NWS receives tornado warnings from the WSR-88D and is responsible for issuing warnings to the general public.

XVI. ITWS AIRPORT LIGHTNING PRODUCT

The ITWS Airport Lightning product provides an indication that lightning has been detected near a specified location. An example of the product is provided in Figure XVI.1. The presence of lightning is indicated by the yellow Lightning alert panel in the Alerts Section of the display.

Figure XVI.1. Example of the Lightning Detection product.

XVI.1 Product Generation

The NLDN provides the raw data that are used by the lightning processor. These raw data reports give the time, location and strength of lightning strikes (primarily cloud-to-ground lightning). These data are quality-edited by comparing the reported location of the lightning strike with an ASR-9 weather channel image collected at the same time. Reported locations are accepted, moved, or rejected depending on their proximity to any weather observed on the radar image.

The lightning warning panel in the Alerts Section of the SD is illuminated whenever lightning is detected within a specified distance of a specified reference location. Generally, the reference location is taken to be the ARP and the distance (*e.g.*, five nautical miles). The specification of a reference location and distance defines a circular region called the Critical Region. The warning panel is illuminated when any validated lightning strike report (*i.e.*, associated with precipitation) is detected within this Critical Region and it will remain on for at least five minutes thereafter.

XVI.2 Display Concept

If cloud-to-ground lightning is detected within the Critical Region, a box in the Alerts Section of the SD turns yellow. The product is updated every 30 seconds and the box will remain yellow for five minutes after the last lightning strike in the Critical Region.

XVI.3 Caveats

The NLDN detects primarily cloud-to-ground lightning; that is, it is relatively insensitive to cloud-to-cloud lightning. In a typical thunderstorm, cloud-to-cloud lightning is much more frequent than cloud-to-ground lightning and also precedes cloud-to-ground lightning by some minutes. The inability of the NLDN to detect cloud-to-cloud lightning thereby prevents any lead-time warning of impending lightning strikes. It takes on average about 15 seconds from the time of the lightning strike to receive and process the data and generate the product.

XVI.4 Operational Use

This product may be used by ATC users to determine when to switch to back-up generator power and by airline users to help in making decisions with respect to refueling and other ground operations.

XVII. EXAMPLES OF DECISION-MAKING WITH THE ITWS PROTOTYPE SITUATION DISPLAY

The SD can be configured to meet each individual users needs and aid in the decision-making process. Some configurations that support specific some of these decisions are presented in this chapter. These configurations illustrate how the multiple-window capability of the SD can be used to monitor a number of locations simultaneously and/or to facilitate the examination of different products at the same time.

XVII.1 Managing Arrival Transition Areas

Some of the benefits of making better air traffic management decisions using ITWS products are outlined in Table I.2. Effectively anticipating the closure and re-opening of Arrival Transition Areas (ATA) are two high-benefit decision-making areas. In terminal areas with multiple ATAs, the traffic manager may need to be able to monitor weather at a number of locations simultaneously. In addition, while the TRACON precipitation product update rate and resolution are better than the other precipitation products, the TRACON product may not adequately cover the ATAs. As a result, the traffic manager may need to monitor the weather over the ATAs using more than one precipitation product.

One possible SD configuration to support managing ATAs, at a four-ATA terminal area such as DFW, is provided in Figure XVII.1. In this configuration, there are six graphics windows; one for each of four ATAs, one centered on the airport, and one displaying the 200-nm precipitation product. The ATA windows are located relative to the airport window in the same way that the ATAs are located relative to the airport. Each ATA window displays the TRACON precipitation product (Chapter III) and is centered on (either by panning or re-centering) the appropriate ATA. These windows are also zoomed in to provide more detail in the vicinity of the ATAs.

The Airport window is centered on the airport and displays the TRACON precipitation product to the full extent of the product (i.e., TRACON range). There is some overlap between the ATA and airport windows to provide continuity between the windows. The five windows displaying the TRACON precipitation product illustrate how multiple windows displaying essentially the same informations can be configured (panned and zoomed) to closely monitor five key locations.

The sixth window displays the 200-nm Precipitation product (Chapter IV) and provides an awareness of the weather situation in the en route airspace. If the TRACON precipitation product does not adequately cover the ATAs, the 200-nm window can be used to monitor weather impacting the ATAs or the 200-nm precipitation product can be displayed in the ATA windows. This allows the user to compare different products at the same time and to take advantage of the strengths of one product over another (in this case, coverage versus no coverage).

In all of the windows, the Storm Motion (Chapter V) and Storm Extrapolated Position (Chapter VI) products are “On”. In the ATA windows, the user may click the middle mouse button on the

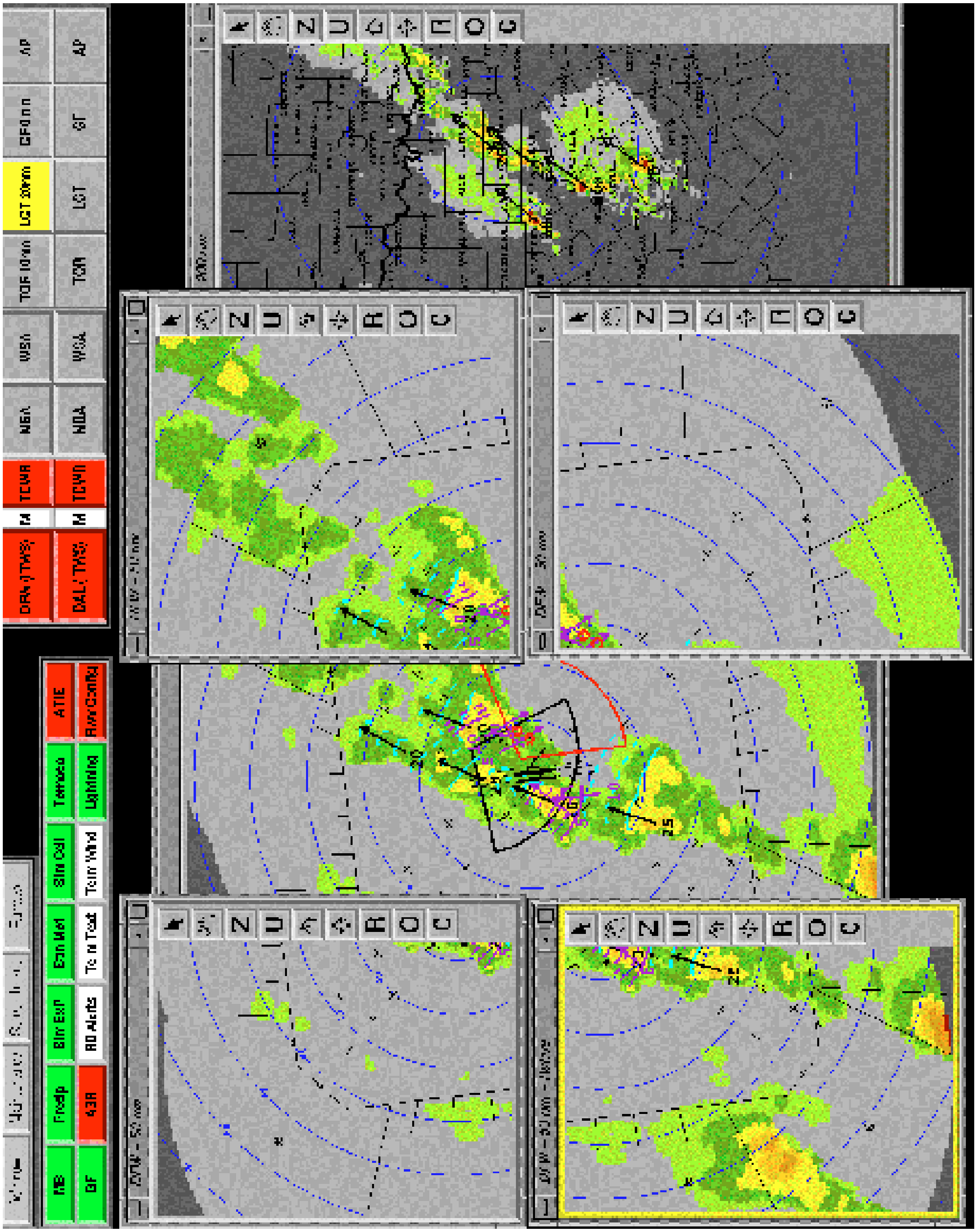

Figure XVII.1. A SD configuration for managing ATAs.

associated ATA to display the storm motion arrows and storm extrapolated position lines for storms closest to the click location (*i.e.*, a user-selection has been made as described in Sections V.2 and VI.2).

Before weather impacts the ATAs, the user can watch the movement of storms outside the TRACON using the 200-nm product window and anticipate, in a broad sense, the impact of the storms on the ATAs. As weather moves closer to the ATAs, the user can use the storm extrapolated position lines to determine within a few minutes when significant weather may reduce or shut off the flow over the affected ATA. Air traffic can be routed pro-actively to ATAs that are not impacted or miles-in-trail restrictions can be considered.

Using the Storm Motion (Chapter V) and Storm Extrapolated Position (Chapter VI) products, the user can anticipate when weather will clear the impacted ATA and route aircraft such that flow over the ATA can commence as soon as possible.

XVII.2 Managing Runways

Effectively managing runways in adverse weather is another high-benefit decision-making area, including recognizing that a runway will remain open, landing more aircraft before airport shutdown, and reducing diversions prior to airport shutdown and near airport re-opening. While the update rate of the TRACON Precipitation product (and associated Storm Motion and Storm Extrapolated Position products) is better than the 5-nm Precipitation product (Chapter II), the ASR-9 based products can underestimate precipitation intensity near the airport (Section III.5). This is especially true when the TRACON Precipitation product consists of input from only one ASR-9 radar.

By adding a window to the configuration shown in Figure XVII.1 and displaying the 5-nm products in it, the user can identify ASR-9 underestimation. Then using the Storm Motion and Storm Extrapolated Position products, the microburst and wind shear products, the gust front forecast and wind shift estimate products, the user can determine when runways will be impacted by adverse weather and plan accordingly.